12-1979

Potential economic and environmental impacts of alternative sediment control policies

Center for Agricultural and Rural Development, Iowa State University

Joseph C. Campbell
Iowa State University

Potential Economic and Environmental Impacts of Alternative Sediment Control Policies

CARD Report 87

THE CENTER FOR
AGRICULTURAL AND RURAL DEVELOPMENT
IOWA STATE UNIVERSITY
AMES, IOWA 50011

POTENTIAL ECONOMIC AND ENVIRONMENTAL IMPACTS OF ALTERNATIVE SEDIMENT CONTROL POLICIES

Joseph C. Campbell and Earl O. Heady

CARD Report 87

Center for Agricultural and Rural Development
Iowa State University
Ames, Iowa 50011

December 1979

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

I. INTRODUCTION

This study focuses on the interaction of U.S. agricultural exports, regional patterns of farm production, and the problem of agricultural sediment. It also evaluates alternative policies in abating sedimentation of the nation's main river basins. One underlying hypothesis of the study is that changes in agricultural export demands cause shifts in the comparative advantage among producing regions within the United States and alter regional land use patterns, farm incomes, consumer food prices, and soil loss. Given this hypothesis, the study uses a mathematical model and two estimates of the U.S. 1985 agricultural exports to investigate if and how these interactions occur.

The second aspect of this study stems from the interaction of agricultural exports and mainstream sedimentation. Changes in agricultural exports which enhance row crop (corn, soybean, and cotton) production increase soil loss. Soil loss not only reduces future farm production, but increased sediment in the nation's waterways also imposes a negative externality on society. In recognizing this possible sediment diseconomy of agricultural exports, the study uses two different policies aimed at restricting sediment to the nation's waterways. The policies are analyzed using the two 1985 export demand estimates, and the results are compared with the no policy (Base) solutions in terms of soil loss, soil conserving practices, regional production patterns, farm incomes, and consumer food prices.

Background of the Study

This section is divided into three parts. First, the role of agricultural exports is discussed. Second, the uncertainty associated with agricultural export demand is examined. This uncertainty led to the use of alternative export demand levels in the study. Finally, the linkage between agricultural exports and sediment is discussed in more detail. This linkage pertains to the second aspect of the study.

The role of exports

The United States has an enormous agricultural production capacity which cannot be economically saturated by domestic demands. Low income elasticities of demand for agricultural products and slow population growth in the domestic market restrict demand and impede supply expansion. On the other hand, exports facilitate production expansion and provide an avenue whereby the United States might realize its full agricultural potential without the use of stringent supply controls or other auxiliary measures to stabilize farm prices and incomes.

More significantly, the value of agricultural exports can provide a large proportion of foreign exchange to American consumers for purchasing imported goods and services. For example, during the boom years of 1971-1975, the value of agricultural exports rose from $7.8 billion in fiscal year 1971 to $21 billion in fiscal year 1975, and the proportion of total export earnings rose from 18 percent in 1971 to 25 percent in 1974 (Table 1). Further, the statistics for the years 1971-1977 show that

Table 1. U.S. merchandise exports and trade balance 1971-1977[a]

Fiscal Year	U.S. Exports (million dollars)			Agriculture contribution	U.S. Trade Balance (million dollars)		
	Agriculture	Nonagriculture	Total	%	Agriculture	Nonagricultural	Total
1971	7,753	35,910	43,663	18	1,925	-986	939
1972	8,046	36,802	44,848	18	1,998	-7,206	-5,208
1973	12,902	44,913	87,815	22	5,578	-9,152	-3,574
1974	21,293	63,631	84,924	25	11,744	-9,323	2,421
1975	21,578	81,280	102,858	21	11,999	-10,201	1,798
1976	22,759	90,032	112,791	20	12,244	-13,964	-1,720
1977	24,014	96,354	120,368	20	10,631	-33,732	-23,101

[a] Domestic exports include Department of Defense shipments (F.A.S.) value.

SOURCE: USDA [22].

the value of agricultural exports acted as a positive influence in stabilizing the balance of trade accounts.

The above roles of U.S. agricultural exports are neither novel nor incidental. The importance is clearly expressed in the U.S. trade policy arrangements which seek to link agricultural and industrial trade arrangements despite strong opposition from other market organizations [18]. Also, Section 103 of the 1974 Trade Act [19] states:

> ....to the maximum extent feasible, the harmonization, reduction, or the elimination of agricultural trade barriers and distortions shall be undertaken in conjunction with the harmonization, reduction or elimination of industrial trade barriers and distortions.

Despite the well-known importance of agricultural exports, farm prices and incomes and foreign exchange earnings continue to fluctuate. One reason for this instability is the uncertainty associated with export demands.

The uncertainty of exports

The demand for U.S. agricultural exports depends upon favorable market forces, world climatic conditions, and institutional arrangements. These components enter the aggregate demand with different "degrees" of uncertainty, adding to the instability of export demand. This instability is transmitted to farm prices and incomes and foreign exchange revenues. Historical evidence has vindicated this effect; amid projections of food scarcity and higher prices in 1966, farm prices and income were again depressed by 1968. The recent experience of the early 1970s provides another example. The prolonged increase in worldwide demand for agricultural commodities and the resulting high farm prices and revenues made many observers, Heady and Timmons [9] and Crosson [5], query whether these forces were new and permanent or transitory. Yet, by early 1977, farm prices and incomes fell, foreign exchange earnings declined (Table 1), and supply control policies became relevant, [16].

Agricultural exports and sediment

Agricultural exports are not independent of soil loss, sedimentation, or agricultural pollution in general. Greater agricultural exports stimulate production thereby facilitating the use of intensive methods. Such methods imply a greater concentration of noxious by-products which create costs to society. In the case of sediment or soil loss, both farmers and the rest of society may be adversely affected.

The major cost of soil loss to farmers is the loss of future productivity. Plant nutrients such as nitrogen and phosphorous are attached to the top soil. Thus, productivity is reduced by greater erosion rates which remove the upper layer of soil. Even in bottom lands less prone to erosion, productivity may be impaired by infertile overwash. However, this cost to farmers may be obscured by factors associated with increasing exports. This cost disguise causes less active farmer participation in controlling soil loss and, therefore, sediment. Evidence to this effect is seen in a survey of farmers participating in the U.S. Department of Agriculture (USDA) conservation program. The study revealed that during the 1971-1975 worldwide increase in export demand, 84 percent of U.S. cropland had soil loss in excess of the recommended level [20].

A number of factors accounts for the decline in importance of the cost of soil loss to farmers in periods of increasing export demands. First, some farmers are faced with institutional arrangements such as land tenure agreements which limit their planning horizon. As a result, the cost of future productivity may not enter their objective function. Second, if the institutional characteristics are negated and farmers are concerned about future productivity, the cost of soil loss may be masked by the use of improved seeds and greater fertilizer applications which tend to maintain or increase yields. Third, even if farmers recognized the cost of soil loss in allocating limited funds, they weigh the benefits with the cost of conservation. Given the knowledge of a present increase in exports and crop prices and the uncertainty of future demands, farmers are apt to relax their goals on soil loss and take advantage of the present profitability of crops. Using a sample of farmers in western Iowa, Hauser and Timmons [7] demonstrated this effect. The study showed that farmers' goals on annual soil loss per acre fell 30 percent between 1952-1957 but increased 24 percent between 1957-1975, indicating a direct relationship between soil loss goals and export demands.

Sediment is generally accepted as the largest polluter of streams, approximately 50 percent by volume [20]. Sediment is present on the nation's roads, in ditches, canals, and rivers. Sediment trapped in ditches and canals reduce their holding capacity, consequently, increasing the danger of floods. For example, in 1964 Ford [6] estimated the sediment-related upstream damage owing to flooding at $87.7 million for the continental United States. Sediment in commercial and navigational waterways represents a hazard and involves a cost of removal. Probably the most important and the most difficult cost to measure is the cost to society resulting from the loss of the aesthetic value of the nation's streams and rivers. Although there is some controversy over the extent to which agricultural sediment contributes to the eutrophic[1] conditions of the nation's waters, it is generally accepted that its role is considerable [4, 15, 29].

The Problem

Agricultural exports may play crucial roles in realizing the United States' full agricultural potential, in buttressing farm income and prices, and in stabilizing foreign exchange earnings. However, export demand uncertainty leads to the following questions: How would production change among the regions of the United States under different long

---

[1]Eutrophication is the process by which a body of water ages [24]. In a closed ecosystem, aging is restricted by the availability of nitrogen and phosphorous in the food chain. Once this system is opened owing to sedimentation, the availability of phosphorous and nitrogen increases, and the process of eutrophication is enhanced. The effect of eutrophication is transmitted to society by increased turbidity in water, beaches with increasing amounts of algae residues, substitution among fish species to less desirable types, and a general reduction in environmental aesthetics.

run export demands? Would some regions experience a gain in comparative advantage or would farm incomes change proportionately in all regions? Greater export demand implies higher domestic food prices. Would the domestic consumer food bill rise significantly or marginally? How would production techniques and soil loss change? Answers to these questions could give policy makers important information for making decisions.

A greater demand for agricultural exports may also result in greater sedimentation since the two are positively correlated. Sedimentation imposes diseconomies on society. If one of society's goals were to reduce sedimentation of the nation's main waterways, then what would be the effect of different policies in achieving this objective? How would the variables mentioned in the previous section change? Would there be drastic or only small marginal differences? Answers to these questions can be useful to decision makers in generating a balance between agricultural structure and its contribution to stream sediment and soil erosion.

Objectives

The objectives of the study are two-fold: The first objective is to quantitatively simulate future national and regional changes in soil loss, agricultural production, and costs under two levels of agricultural exports. The two demand levels project "low" and "high" export alternatives congruous with the uncertainty associated with agricultural exports. The second objective is to investigate the impact on sedimentation of two policies aimed at reducing sediment in the nation's waterways. The two policies are: (a) the 5 Ton Limit which restricts sediment through a physical regulation on crop production requiring activities with no greater than five tons of gross soil loss per acre annually,[2] and (b) the "Tax" policy which uses a cost (tax) on sediment actually reaching the main river basins to generate the same national sediment standard[3] as the 5 Ton Limit.

---

[2]A gross soil loss of five tons per acre annually is generally accepted as the erosion rate which maintains soil fertility over time, [3, 10].

[3]Standards pertain to sediment actually reaching the main river basins.

II. METHODOLOGY AND MODEL

Methodology

In its effect on mainstream sedimentation, sediment can be treated as an externality. As a result, the Pigouvian (taxes-subsidies) approach in controlling sediment becomes relevant. In the strict Pigouvian analysis, a tax (subsidy) equal to the marginal net social damage (benefit) is placed on the externality-producing activity to generate an optimal level of control [1, 14]. In practical application, however, the analysis suffers from two critical problems. First, the measurement of marginal net social damage (benefit) is difficult. For example, some of the costs associated with sediment externalities are psychic and intangible: the present and future losses of recreational services prevent reasonable cost estimates. Second, there exists the question of what is the optimal rate of control? If the answer to this question were known, then the optimal tax rate could readily be calculated.

To circumvent the above two difficulties, Baumol and Oats [2] and Baumol [1] purported a modified version of the Pigouvian tax (subsidy) scheme denoted as the method of Standards and Prices. Essentially, the method suggests the specification of an arbitrary[1]

[1] The word arbitrary is used in the sense that the standard is not based on theory, but more so on past observations and researchers' experience.

tolerable standard of effluent and the use of the price mechanism (tax or subsidy) to generate the same standard. The final step involves the adjustment of the standards to iteratively determine the optimal prices and standards. The adjustments here are based on weighing the benefits and the cost of an alternative standard.

The Standards and Prices method provides two policies for comparison: (a) the standard as given by a regulation and (b) the price mechanism consistent with a tax (subsidy). In this study, the 5 Ton Limit was the regulation specifying the sediment standard. A tax on sediment was a relevant policy instrument for generating the standard.

The Model

The analysis of this study is made by an interregional linear programming model using projected 1985 conditions. The basic model is one of a series developed by the Iowa State University-Research Applied to National Needs (ISU-RANN) project used to simulate U.S. agriculture [8, 13, 28]. The model is set up to minimize the total social cost of producing and transporting agricultural commodities and the environmental cost of sedimentation in the main river basins. Total social cost is minimized, given fixed point demands for agricultural commodities. Production is constrained by the availability of land resources, water supplies, and permanent hay and nitrogen fertilizer.

We present a mathematical summary of the model to illustrate the policy alternatives. Subsequent discussions include the delineation of regions and sectors of the model.

Mathematical Description of the Model

In matrix notation, the basic model can be written as follows:

Minimize $P + t.S$ (1)

subject to $[C_1\ C_2]\ [X_1\ X_2]' - 1P = 0$ (2)

$[A_1\ A_2]\ [X_1\ X_2]' \geq b$ (3)

$[D_1\ D_2]\ [X_1\ X_2]' - IS = 0$ (4)

$P, S, X_1, X_2 \geq 0$ (5)

where:

P is a scalar representing the total cost of producing and transporting agricultural commodities;

t is a vector of cost 't' on sediment reaching the main river basins;

S is a (k x 1) vector of sediment actually reaching the main river basins;

C_1 and C_2 are $(1 \times n_1)$ and $(1 \times n_2)$ vectors of production and transshipment costs;

A_1 and A_2 are $(m \times n_1)$ and $(m \times n_2)$ matrices of technical production and transshipment coefficients;

b is an (m x 1) vector of resource availabilities and demand requirements;

D_1 and D_2 are $(k \times n_1)$ and $(k \times n_2)$ matrices of coefficients delineating the sedimentation process from the crop production activities to the main river basins;

I is a $(k \times k)$ identity matrix;

X_1 and X_2 are the production and transshipment activities; and

X_2 contains all crop production activities with soil loss greater than five tons per acre annually.

The basic model specified above is modified in simulating the alternative solutions. For the Base solutions, the tax "t" on sediment reaching the main river basins is set equal to zero. The model then minimizes the total cost of producing and transporting agricultural commodities, P, without any soil loss or sediment restrictions. With the 5 Ton Limit, not only is "t" or tax set equal to zero, but all X_2 activities are eliminated. This results in the minimization of total costs with the requirement that the soil loss from all crop production activities, including production techniques and erosion control measures, be no more than five tons per acre annually. The Tax Policy uses the basic model with "t" equal to 50. This implies that total social cost is minimized with a $50 per ton tax on sediment reaching the main river basins, and without soil loss restriction on production activities. The low and high export solutions are obtained by adjusting the vector "b".

The value of "t" used in the Tax Policy solutions is obtained from coordinating two approaches. First, the basic model is modified as specified by Equations (6) through (10).

$$\text{Minimize} \quad P \tag{6}$$

$$\text{subject to} \quad [C_1 \ C_2] \ [X_1 \ X_2]' - 1P = 0 \tag{7}$$

$$[A_1 \ A_2] \ [X_1 \ X_2]' \geq b \tag{8}$$

$$[D_1 \ D_2] \ [X_1 \ X_2]' \leq c \tag{9}$$

$$P, X_1, X_2 \geq 0 \tag{10}$$

where:

c is the (k x 1) vector of the 5 Ton Limit's sediment reaching the main river basins.

Simulation of the above model generates k shadow prices for sediment actually reaching the main river basins. This indicates an initial value of "t." The second step incorporates this starting value of "t" into the basic model, and "t" is iterated until the national sediment, levels under the two policy alternatives, the Tax and the 5 Ton Limit, are identical. In so doing, a "t" or tax value of $50 was adequate at both export levels.

The Regions of the Model

Four regional delineations are used in the model. They are the regions within which the data are collected, the producing areas within which production activities are defined, the market regions which act as a central point of commerce, and the reporting regions into which the results are summarized.

The data regions

The data were collected on the basis of political and geographic regions. These regions included the counties and states of the continental United States from which census and commodity production data are tabulated. In addition, data were obtained from the county approximations of the major land resource areas as delineated by the data collecting agency of the Soil Conservation Services (SCS), U.S. Department of Agriculture. Figure 1 shows the location of these regions.

The producing areas

A total of 105 producing areas are defined in the model. They are county aggregations of river subbasins as provided by the Water Resource Council for developing the 1975 National Water Assessment [23]. The producing areas (PAs) are hydrologically consistent in terms of water flow and serve as subsectors of larger river basins which can be approximated by linking appropriate PAs. Figure 2 shows the 105 PAs nested within the river basins. The heavier lines demarcate the major river basins.

All crop production activities are defined within the PAs. Thus, the relevant inputs such as the land base and the water supply used in these production processes are also defined on a PA basis.

The market regions

Twenty-eight contiguous market regions (MRs) are defined (Figure 3) from aggregation of the 105 PAs. The MRs serve two purposes. First, they

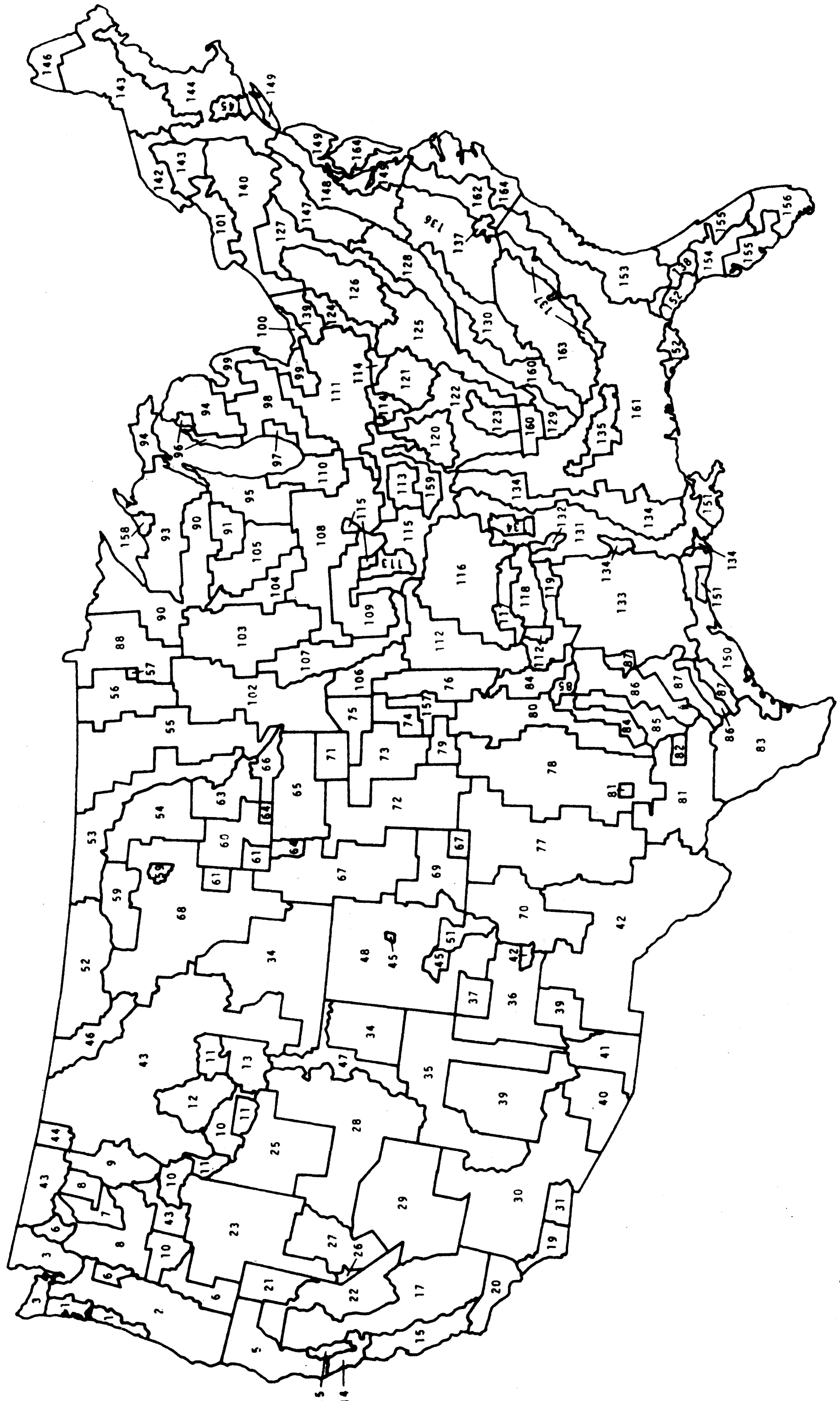

Figure 1. The SCS data collection areas

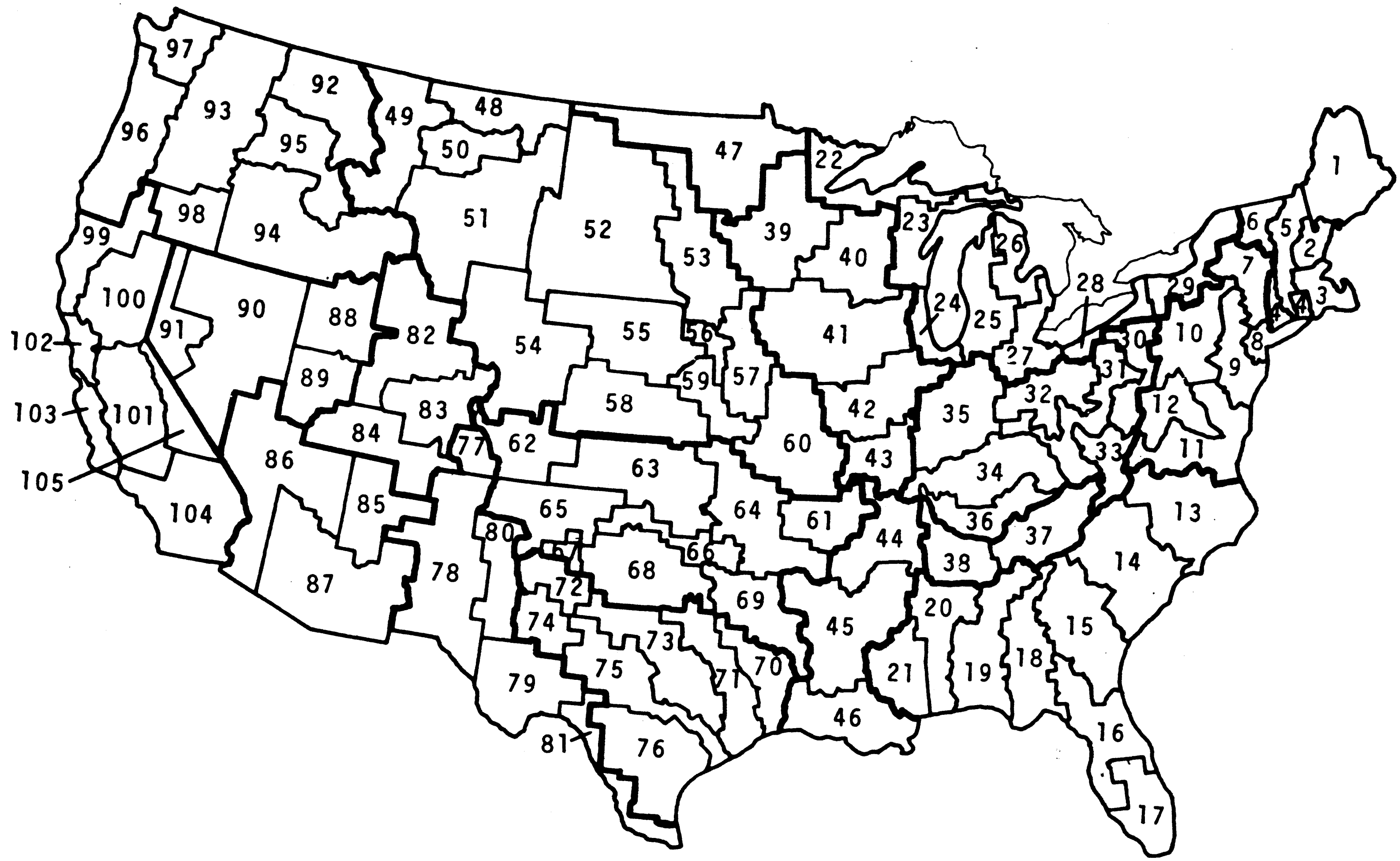

Figure 2. The 105 producing areas nested within the main river basins

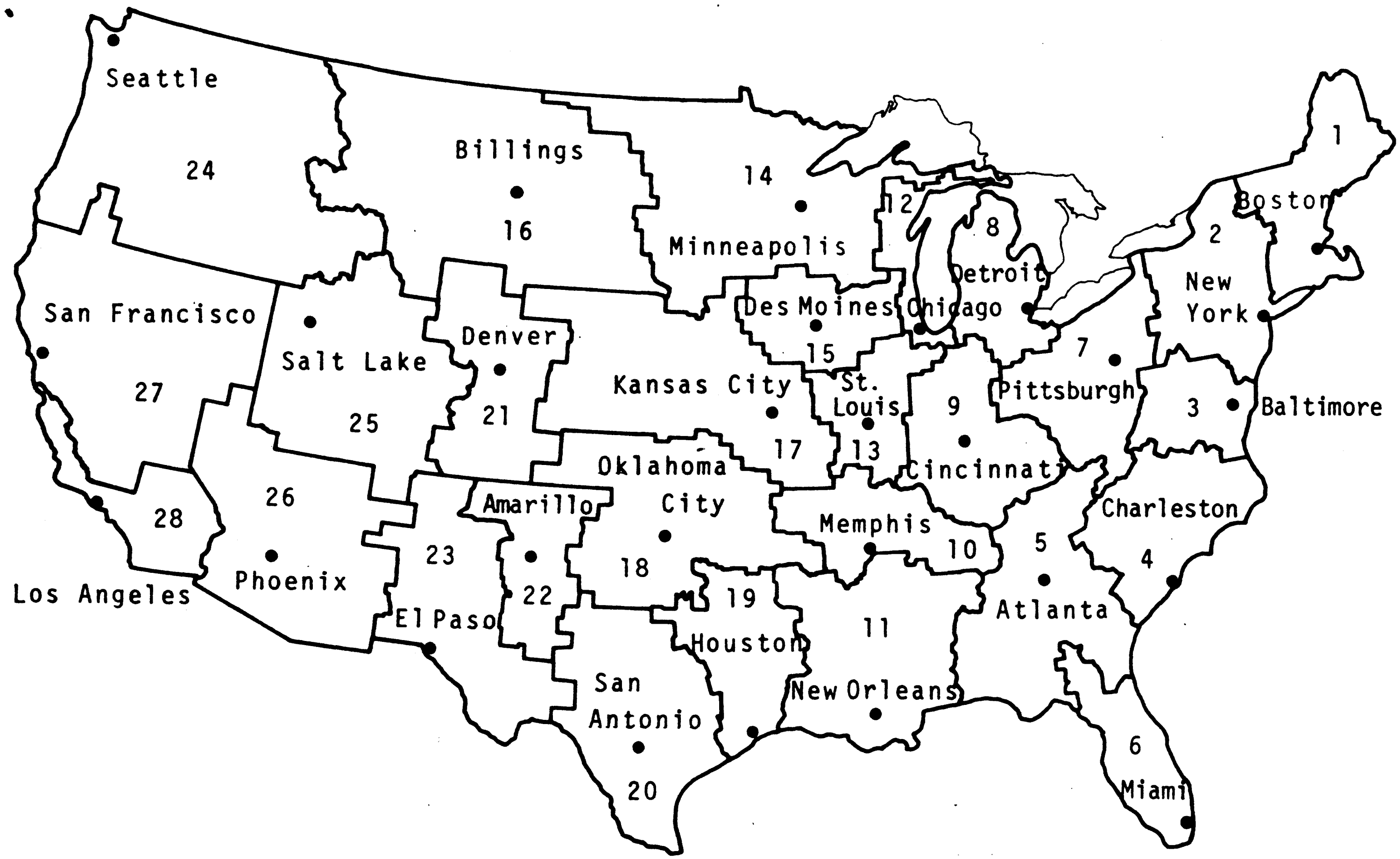

Figure 3. The 28 market regions with central cities indicated

are the demand regions for the major commodities, and therefore, represent the spatial complement of the model through which intermediate and final products are shipped. The metropolitan center identified within each MR acts as a hub for these processes. It is through the spatial linkages that the relative comparative advantages and changes in production patterns are determined among the regions of the model in fulfilling the demand restraints.

Second, the endogenous livestock and relatively immobile crop producing activities are defined in these market regions. Computational ease is the main reason for defining these activities by MRs rather than by PAs.

The reporting regions

The reporting regions are shown in Figure 4. These are more or less arbitrarily assigned on the basis of regional importance and convenience.

Major Sectors of the Model

The model has seven major sectors. These include the land, crop production, soil loss and sediment, livestock, water supply, commodity demand, and transportation sectors. Implicitly, the model also includes an exogenous agricultural sector. The exogenous sector accounts for the resource utilization by the nonendogenous crops and livestock activities. The exogenous sector is explained before the other seven major sectors.

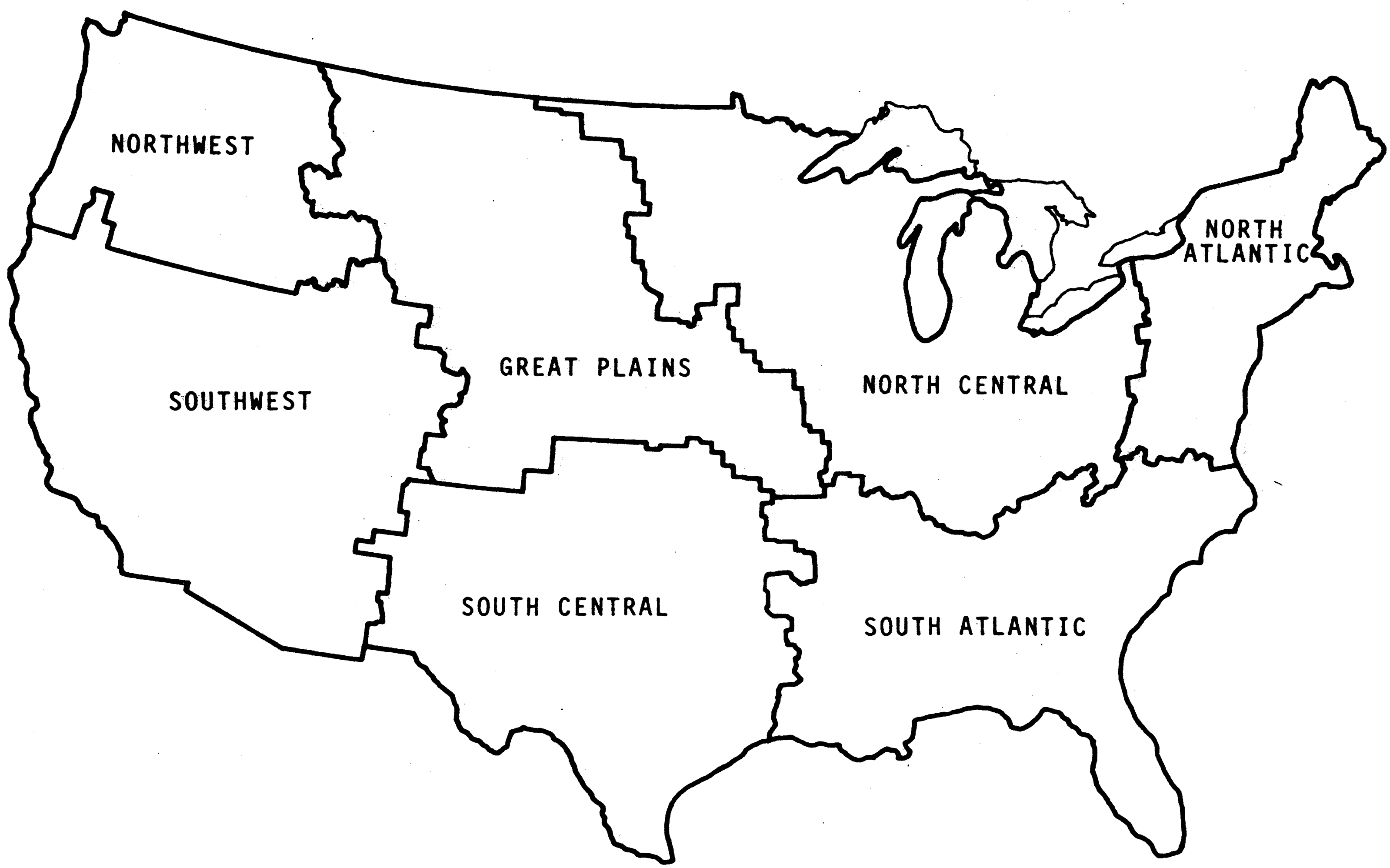

Figure 4. The seven reporting regions

The exogenous agricultural sector

The exogenous enterprises can be divided into two groups: (a) fruits and vegetables and minor field crops and (b) the small, extremely intensive animal enterprises. The first group includes dry beans, dry peas, flax seed, fruits and nuts, peanuts, potatoes, rice, rye, sugar cane, sweet potatoes, tobacco, and similar fruit, vegetable or spiced crops. The second contains broilers, eggs, turkeys, sheep and lambs, and other minor animals (horses, mules, ducks, geese, fur-bearing animals, and zoo animals).

The exogenous activities exert influence on the model through the *a priori* withdrawals of resources and in the case of animals, also via nitrogen fertilizer supplied. Commodity demands for exogenous crops are projected to the year 1985. Then, the land acres, water supply, and fertilizer necessary to support these levels are removed from the resource base. In the case of land, some minor adjustments are necessary, which account for double cropping and reduce the available exogenous acreage [13].

Exogenous livestock activities consume appropriate amounts of water resources and feed. Water resources are withdrawn from the base supplies while the feed is extracted from supplies representing an addition to the endogenous demands. The feed demands are based on the rations for each class of animal explained in Agricultural Water Demands [8] and projected 1985 animal numbers. Nitrogen wastes from exogenous animals are converted to nitrogen fertilizer equivalents and serve as additions to available nitrogen supplies.

Permanent nonleguminous hay and pasture are converted exogenously into hay equivalent and made available as roughage to endogenous livestock activities. The nonleguminous hay and pasture are determined from the Conservation Needs Inventory (CNI) [21]. They include range and grazed private and public forest lands.

Land sector

The land base in the model is based on the CNI data [21] which included a sample of privately owned land by agricultural capability class. The report delineated eight major land capability classes (I-VIII). These classes were further subdivided into 29 subclasses on the basis of hazards restricting use. The hazards or subclasses reflected the susceptibility to erosion (e), subsoil exposure (s), drainage problems (w), and climatic factors preventing normal crop growth (c).

The land acreages were aggregated by county and class-subclass into the PAs (producing areas) where adjustments for exogenous crop uses were made. For this model, the land classes were further aggregated into five (dry and irrigated) groups for use in the study. Table 2 reports the class-subclass delineation within a group and the national land base for each group.

Table 2. Five land groups (classes) and their respective national endogenous land base[a]

Groups Used in Study	Class-Subclass	Total Endogenous Acres (000 acres)
1	I, IIwa, IIIwe	65,084
2	rest of II, and IV; all of V	213,287
3	IIIe	71,113
4	IVe	29,642
5	VI, VII, VIII	14,466

[a]A definition of these land classes can be found in Meister and Nicol [12].

The crop production sector

In the endogenous crop production sector, technically efficient activities are defined for the following crops: barley, oats, grain sorghums, wheat, corn, cotton, soybeans, legume and nonlegume hays, and sugar beets. Different activities are defined for different rotations in each of four conservation methods and each of three tillage practices in each land class in each PA. These activities consist of one to four crops in rotational combination for periods of one to eight years. The four conservation methods are straight row cropping, contouring, strip cropping, and terracing. The three tillage practices are conventional tillage residue removed, conventional tillage residue left, and minimum tillage. The rotational combinations used in delineating each activity were based on historical information, while the conservation methods and tillage practices were recommendations obtained from the Soil Conservation Services (SCS) questionnaire [12].

Production activities designate the amount of land, water, nitrogen fertilizer, and other resources used in the production of crops, crop aftermaths, and soil loss. Production costs also are associated with each production activity.

Production activities are based on a unit acre of land. The water coefficients represent the net of precipitation required for stated crop yields and are, therefore, relevant in the 17 western states where irrigated cropping methods are defined. Nitrogen fertilizer requirements depend on the crop yields and the rotational combination used. Larger crop yields require larger nitrogen use. Nitrogen fertilizer adjustments are made for rotational sequences involving leguminous crops and which need less chemical nitrogen. Yields were obtained from production functions developed by Stoecker [17]. These yields, projections to 1985, vary by land class, PA, cropping method (dryland or irrigated), tillage and conservation practices, and the rotational delineation. Apart from cotton and soybeans, the production of each crop is associated with an estimate of aftermath in terms of hay equivalents. The aftermath yields are modifications of Jennings estimates [11].

The production costs were defined for each activity to reflect 1985 conditions. Costs depend on crop yields and, therefore, on the variables previously delineated which influence yields. They do not reflect returns to land or any fixed costs associated with land. Returns to land are determined endogenously.

Soil loss and sediment sector

This sector can be divided into two component parts, namely, the gross soil loss and the sediment subsectors. The latter defines the quantity of gross soil loss estimated to actually reach the main river basins.

Gross soil loss subsector Gross soil loss represents the average annual soil loss leaving the land and emanating from the production activities. The study is not concerned with gross soil loss *per se*. However, it is used in an accounting sense to determine total and average gross soil loss per acre; to identify activities with greater than five ton gross soil loss, and as a basis to calculate the sediment actually reaching the major river basins.

Gross soil loss estimates were determined in two separate ways. For areas east of the Rocky Mountains, the "Universal Soil Loss Equation" as outlined by Wischmeier and Smith [30] was used. The equation relates average annual soil loss in tons per acre as a multiplicative function of erosivity, erodibility, slope length, slope gradient, crop management practices, and erosion control practices. It is stated in the following manner:

$$A = R \times K \times L \times S \times C \times P \tag{11}$$

where:

A is the average annual gross soil loss in tons per acre;

R is the average rainfall erosive index per year for the particular location, soil and precipitation;

K is the soil erodibility factor for the particular soil depending on its structure and other characteristics relative to its erosion under continuous fallow on a nine percent slope of 72.6 feet long;

L is the slope length relative to a 72.6 feet slope length;

S is the slope gradient relative to a nine percent slope;

C is the cropping management factor which hinges upon the particular cropping sequence and tillage practices; and

P is the erosion control factor (practice) which depends upon the soil conservation practices used.

The alternative procedure used in computing gross soil loss estimates was based on data collected from the SCS questionnaire [21]. The data areas for this procedure included the agricultural lands in the Mountain valleys and the West coast. We assume consistency between the "Universal Soil Loss" and the SCS estimates. In fact, the assumptions are the same where the two estimation procedures overlap.

Sediment subsector Not all sediment leaving agricultural lands reaches main water bodies. Restraints on the movement of soil particles are caused by natural and artificial entrapments. These structures, whether they are highways, streams or grasslands, restrict the movement of soil particles and reduce the proportion actually reaching the mainstreams. The latter proportion is responsible for navigational hazards, eutrophication and other negative environmental externalities.

Wade [27] made estimates of the sediment delivery and transport ratios by PA. These ratios respectively show the proportion of sediment reaching the PA mainstream and the distribution of the sedimentation in downstream PAs. Table 3 shows these delivery ratios by PA. These sediment delivery estimates were computed by taking the ratio of the average annual sediment load, after adjusting for sediment transport, to the annual gross soil loss. The transport ratios, which represent the proportion of sediment delivered to a river from an upstream PA, are shown in Table 4. For further details, see Wade [27].

Given the sediment delivery and transport ratios and the schematic river flow (Figure 5), then the quantity and distribution of sediment deposited in the main river basins from any crop production activity can be computed. The procedure is illustrated as follows:

Let

D_j be the delivery ratio for PA_j;

T_j be the transport ratio for PA_j;

GS_{ij} be the gross soil loss in tons per acre for activity i in PA_j;

and

$F_{ij} = D_j \times GS_{ij}$ is the total soil loss in tons per acre emanating from activity i in PA_j actually reaching the main river basin associated with PA_j.

Then, there exist coefficients, S_{ijk}, of the form: $F_{ij}(1-T_1)$, $F_{ij} \times T_1(1-T_2)$; $F_{ij} \times T_1 \times T_2(1-T_3)$; . . . $F_{ij} \times T_1 \times T_2 \times$ . . . $T_{n-1}(1-T_n)$, which describe the sediment transportation process for that activity, where:

$i = 1, 2, \ldots, m$;

$j,k = 1, 2, \ldots, 105$;

Table 3. Sediment delivery ratios used in the model to compute sediment from soil loss

Producing Area	Sediment Delivery Ratio	Producing Area	Sediment Delivery Ratio	Producing Area	Sediment Delivery Ratio	Producing Area	Sediment Delivery Ratio
1	.016	28	.03	54	.032	80	.022
2	.016	29	.03	55	.032	81	.001
3	.041	30	.03	56	.032	82	.064
4	.041	31	.064	57	.112	83	.058
5	.041	32	.03	58	.037	84	.213
6	.04	33	.03	59	.037	85	.077
7	.025	34	.185	60	.111	86	.023
8	.025	35	.03	61	.074	87	.001
9	.012	36	.01	62	.03	88	.01
10	.016	37	.01	63	.024	89	.01
11	.01	38	.134	64	.032	90	.01
12	.008	39	.001	65	.004	91	.01
13	.006	40	.028	66	.022	92	.01
14	.005	41	.049	67	.01	93	.043
15	.004	42	.05	68	.019	94	.01
16	.003	43	.05	69	.053	95	.057
17	.003	44	.043	70	.006	96	.068
18	.002	45	.035	71	.012	97	.01
19	.016	46	.258	72	.007	98	.01
20	.019	47	.014	73	.081	99	.378
21	.012	48	.079	74	.001	100	.021
22	.03	49	.074	75	.018	101	.003
23	.03	50	.161	76	.008	102	.018
24	.03	51	.322	77	.01	103	.107
25	.03	52	.003	78	.001	104	.005
26	.03	53	.007	79	.059	105	.01
27	.03						

SOURCE: Wade [27].

Table 4. Sediment transport ratios used in the model to complete sediment deposition from upstream PAs

Producing Area	Sediment Transport Ratio	Producing Area	Sediment Transport Ratio
8	1.000	59	1.000
31	.513	60	1.000
34	.735	63	.270
38	.001	64	.228
40	.700	66	.110
41	.400	68	.067
42	.540	69	1.000
43	.950	73	.026
44	1.000	75	.003
45	1.000	78	.106
46	1.000	79	.188
48	1.000	81	.334
50	.029	84	.038
52	.001	86	.016
53	.838	93	.007
55	1.000	95	.256
56	1.000	96	1.000
57	1.000		

SOURCE: Wade [27].

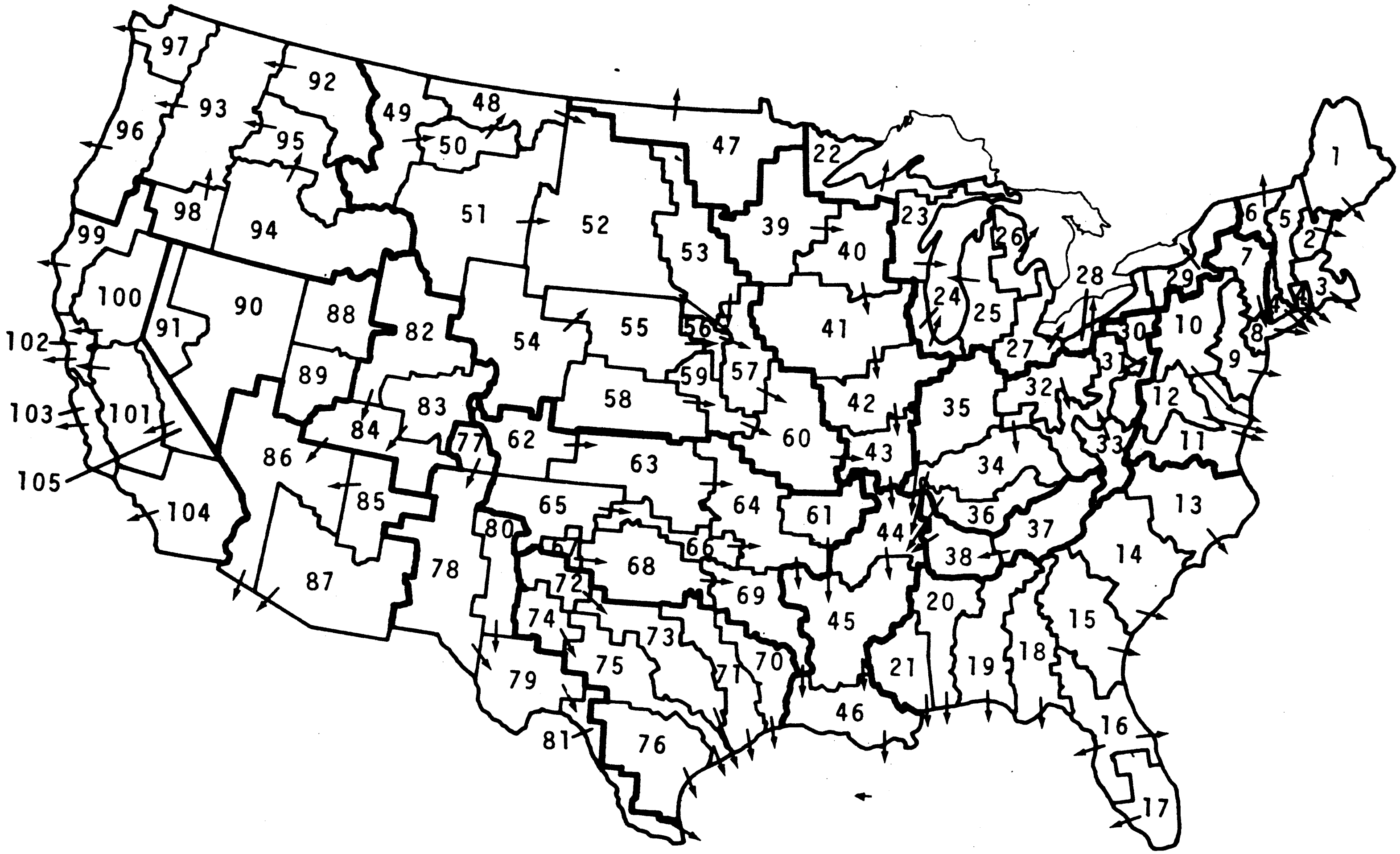

Figure 5. Schematic river flows for sediment transport

m is the total number of activities in PA_u;

n is the total number of downstream PAs as indicated by the river flow system; and

S_{ijk} is the quantity of sediment in tons per acre actually reaching the river basin in PA_k from activity in in PA_j.

The final complement of the soil sedimentation subsector is a linkage to the objective function independent of production costs. The schematic river flows are shown in Figure 5.

In summary, the sedimentation subsector exhibits two features. First, it accounts for the locational differences in sedimentation in the sense that the soil loss from a given endogenous production activity in an PA (say 45) may be deposited in the river basin in another PA (say 46). Second, the independent linkage to the objective function increases the computational efficiency in evaluating policy alternatives.

The livestock sector

The endogenous livestock activities are defined by market regions. They represent four classes of livestock, namely, dairy cows, hogs, beef cows, and beef feeding. Each activity is associated with a ration, a direct cost of production, and a nitrogen supply coefficient which stems from manure production.

Each type of livestock can choose from a number of rations determined endogenously to the model. The rations allow different permutations among crops in producing one unit of livestock. Substitutability among rations can take place among grains, between grains and roughages, and among roughages given the grain component. Rations are formulated with embedded restrictions which guarantee palatability by the livestock consuming class.

Two sets of costs are involved in producing one unit of livestock activity. First, the direct costs are included in the "objective function." These costs are explained by Nicol and Heady [13] and account for differential rates of livestock capital utilization among the various market regions. Second, there is an indirect or implied cost associated with the shadow prices of the crops which define the rations. Given identical direct costs, the model chooses the least cost ration in terms of the internally generated crop prices.

The manure by-product of livestock enterprises represents a possible contribution to nitrogen fertilizer. The model converts livestock manure into nitrogen equivalents and makes it available for use by endogenous crop production activities.

Water sector

The water sector is developed to simulate endogenous water usage in the western states where irrigation practices occur. In the eastern states, water activities are not defined where water availability exceeds agricultural demands and generally is too costly to use for crop irrigation.

Water supplies are defined by PA (Figure 2) for PA 48 through PA 105 inclusive. The sources of the supplies include surface and groundwater after adjustments are made for nonagricultural water requirements and transit losses. The availability of water in any given PA depends on the natural flows and interbasin transfers from other PAs within specified limits.

There also is a cost by PA associated with the water flow system. These costs are based on the water delivery and pumpage charges and are derived from data obtained from the Bureau of Reclamation irrigations projects [24]. Further details concerning the water sector and the development of water prices can be found in Meister and Nicol [12].

Commodity demand sector

The demand sector specifies the point demand for each commodity in each market region. This sector is the driving force of the model in the sense that it states the minimum quantity of the endogenous commodities necessary to quarantee the 1985 projected consumption of food and fiber, net exports, exogenous livestock production, and industrial and other nonfood uses.

Two alternative demand levels are used in the study. These demands are based on a projected national population of 233 million for the year 1985. Domestic utilization of commodities are the same in both demand scenarios but estimates of the net exports are based on the OBERS E' "high" and a deviant of the OBERS E' export projections [25, 26]. The low export demand is the OBERS E' "high" estimate, while the high export demand uses the OBERS E' adjusted with a fixed proportionate increase of .486, .07, .199, and .245 in corn, sorghum, wheat, and soybeans, respectively, to the levels indicated in Table 5. The high export demand exhibits a bias towards row crops--soybeans in particular.

Table 5. Projected 1985 net exports: OBERS E', the low and high demands used in the study

Item	Unit	Export Quantities - Millions		
		OBERS E'	OBERS E' "high" (low export demand)	OBERS E' "adjusted" (high export demand)
Corn	bu.	989	1,889	1,875
Sorghum	bu.	160	270	288
Barley	bu.	20	25	20
Oats	bu.	10	19	10
Wheat	bu.	774	1,179	1,137
Soybeans	bu.	950	1,125	1,397
Cotton	bale	4.1	4.2	4.1
Beef & veal (carc. wt.)	lbs.	-2,169	-1,190	-2,169
Milk (fresh equiv.)	lbs.	-680	-680	-680
Pork (carc. wt.)	lbs.	-307	-307	-307
Lamb & mutton (carc. wt.)	lbs.	-230	-230	-230
Turkeys (R.T.C.)	lbs.	70	70	70
Broilers (R.T.C.)	lbs.	235	235	235
Eggs	doz.	44	43.9	44

The transportation sector

This sector delineates the transshipment network among market regions. In general, routes are defined between contiguous market regions. In some cases, however, noncontiguous market region routes are defined if such specifications reduce the mileage by more than 10 percent vis-a-vis the normal routes.

For every commodity shipped, two routes link each pair of market regions. This facilitates the movement of the commodity in both directions.

Transshipment costs are associated with the movement of each commodity. These costs are proportional to the distance between market regions, since a uniform rate is charged over all routes, given the commodity.

III. RESULTS

The results of the study are presented in this section. First, the two Base solutions reflecting alternative 1985 U.S. export demands in the absence of sediment policies are compared. The effects of the 5 Ton Limit and Tax Policy are then compared relative to the Base scenarios. The low export Base solution represents the relevant reference point for the low export Tax and 5 Ton Limit solutions unless otherwise specified. Similar comparisons are made for the high export solutions.

In the large-scale model used in the study, not all results could be analyzed and presented. A choice of data important to summarize had to be made. In this report, the variables discussed are the environmental impacts, conservation and tillage practices, land and other resource use, crop and livestock patterns, food prices, and farm incomes. These variables are analyzed at the national level and by reporting regions where relevant.

The Environmental Impacts

The main environmental variable considered is sediment, although gross soil loss and average gross soil loss per acre are introduced to complete the analysis. National and regional changes in sediment relative to the Base solutions are first delineated. Then, the effect of the policy solutions (Tax and 5 Ton Limit) are compared. Similar analyses are pursued for gross soil loss. Some observations concerning average gross soil loss per acre are also mentioned.

Sediment

Total sediment load in the United States is 83 million tons under the lower export Base. Of this sediment, 78 percent is located in the South Atlantic region and 16 percent is in the combined North and South Central regions (Table 6). The large sediment deposition in the South Atlantic region is caused by (a) the relatively greater erosivity of the region and (b) the river flow system into the region (Figure 5) which encourages sediment transportation from upstream regions.

The high export Base solution results in an increase in the national sediment load to 95 million tons. The South Atlantic region shows the largest change, followed by the Great Plains and Western regions. These changes in sediment are related to (a) the increase in the amount of land required to satisfy the greater export requirement, (b) the greater use of more erosive lands, and (c) the change in the exports demands encouraging production of the more erosive row crops.

The two policy alternatives (Tax and 5 Ton Limit) reduce national sediment load by approximately 65 percent relative to the Base solutions (Table 6). Similar reductions in national sediment load are expected under the policies given their construction. However, the similarity between the two policies on sediment at the national level is not transmitted throughout the regions. In the North and South Atlantic regions the 5 Ton Limit is more effective than the Tax policy in reducing sediment,

Table 6. Regional sediment loads, and as a percentage of the Base for the six solutions

Item	Sediment			
	Low Export		High Export	
	(000 tons)	% of Base	(000 tons)	% of Base
		North Atlantic		
Base	790	100	824	100
Tax Policy	456	58	668	81
5 Ton Limit	330	42	326	40
		South Atlantic		
Base	64,998	100	75,696	100
Tax Policy	20,731	32	25,177	33
5 Ton Limit	21,766	33	23,953	32
		North Central		
Base	6,950	100	7,085	100
Tax Policy	4,434	64	5,015	71
5 Ton Limit	4,752	68	4,672	66
		South Central		
Base	6,300	100	6,625	100
Tax Policy	2,257	36	2,619	40
5 Ton Limit	1,439	23	1,672	25
		Great Plains		
Base	2,102	100	2,429	100
Tax Policy	446	21	781	32
5 Ton Limit	1,076	51	1,169	48
		Northwest		
Base	1,527	100	1,762	100
Tax Policy	676	44	784	44
5 Ton limit	849	56	971	55
		Southwest		
Base	324	100	372	100
Tax Policy	249	77	239	64
5 Ton Limit	313	97	414	111
		United States		
Base	82,991	100	94,793	100
Tax Policy	29,249	35	35,283	37
5 Ton Limit	30,325	37	33,177	35

but in the Great Plains and Western regions the opposite is true. The effectiveness of the 5 Ton Limit is linked to regional erosivity. The policy encourages soil conserving techniques in the erosive regions. Hence, it is more effective in abating sediment in the Atlantic regions. In the case of the Tax Policy, regional productivity hinders the use of soil conserving techniques where the profitability of commodities outweighs the tax effect sediment. This effect is further enhanced due to higher commodity prices under the high export case.

Gross soil loss

National gross soil loss increases by 7 percent under the high export Base relative to the low export Base (Table 7). The North Central, South Atlantic, and the combined South Central and Great Plains regions account for most of the soil loss. However, the South Atlantic region is the most erosive region. The region has average gross soil losses per acre of 12.06 tons and 12.64 tons under the low and high export Base runs, respectively--values which are more than double those of any other region (Table 7).

The increases in national soil loss under the high export Base is caused by greater land utilization and the production of more erosive crops. However, larger prices for commodities under the high export Base also encourages the use of soil conserving techniques in areas where these practices are beneficial for crop yields. This latter effect is evident in the North Atlantic region where more terracing practices cause gross soil loss and average gross soil loss per acre to decline

Table 7. Regional gross soil loss, and as a percentage of the Base, and average gross soil loss/acre for all solutions

	Total Gross Soil Loss				Gross Soil Loss tons/acre	
	Low Export		High Export			
	(000 tons)	% of Base	(000 tons)	% of Base	Low Export	High Export
			North Atlantic			
Base	65,797	100	65,042	100	5.82	5.48
Tax Policy	37,224	57	55,704	86	3.29	4.78
5 Ton Limit	29,256	44	28,082	43	2.61	2.45
			South Atlantic			
Base	469,666	100	530,394	100	12.06	12.64
Tax Policy	368,264	78	382,387	72	9.97	9.60
5 Ton Limit	133,648	28	147,236	28	3.58	3.58
			North Central			
Base	649,099	100	694,271	100	4.86	5.03
Tax Policy	440,984	68	463,903	67	3.28	3.36
5 Ton Limit	372,304	57	403,790	58	2.74	2.89
			South Central			
Base	291,616	100	292,244	100	5.17	4.73
Tax Policy	187,538	64	202,621	69	3.14	3.31
5 Ton Limit	114,487	39	133,311	46	2.00	2.14
			Great Plains			
Base	345,272	100	363,697	100	5.20	4.80
Tax Policy	81,765	24	102,850	28	1.30	1.37
5 Ton Limit	133,170	39	143,984	40	2.22	1.84
			Northwest			
Base	39,063	100	43,882	100	2.95	3.17
Tax Policy	21,052	54	27,025	62	1.65	2.09
5 Ton Limit	22,819	58	24,600	56	1.79	1.67
			Southwest			
Base	12,414	100	12,540	100	1.36	1.26
Tax Policy	9,133	74	9,544	76	1.03	0.96
5 Ton limit	10,787	87	9,338	74	1.16	0.87
			United States			
Base	1,872,929	100	2,002,013	100	5.69	5.60
Tax Policy	1,145,963	61	1,244,038	62	3.56	3.57
5 Ton Limit	816,475	44	890,343	44	2.45	2.48

relative to the low export Base, despite greater row crop production under the high export Base.

Compared to the Tax Policy, the 5 Ton Limit proves to be significantly more effective in reducing gross soil loss than the former at the assumed tax level. At both export levels, the 5 Ton Limit reduces national gross soil loss by 56 percent relative to the Base solutions. The corresponding reduction by the Tax Policy is approximately 39 percent. The 5 Ton Limit is more effective than the Tax Policy in reducing soil loss in the Atlantic and South Central regions. However, the opposite is true in the Great Plains region and to a lesser extent in the Western regions (Table 7) where erosion is relatively less and the Tax Policy puts a heavy cost on it.

The overall greater effectiveness of the 5 Ton Limit on soil loss is manifested in the national average soil loss per acre. The 5 Ton Limit generates a national average gross soil loss per acre of 2.5 tons compared with 3.6 for the Tax Policy used. These averages are considerably below the Base solution national average of 5.65 tons per acre. However, the level of the penalty under the Tax Policy could be raised to lower the national average also to 2.5 tons. The amount is still to be determined.

The main reasons for the disparity between the 5 Ton Limit and the Tax Policy on soil loss are: (a) the relative ineffectiveness of the tax on sediment in inducing conservation practices in highly productive regions, and (b) the 5 Ton Limit's restriction on gross soil loss regardless of productivity. In productive regions the profitability of crops may outweigh the cost induced by the tax on sediment. Hence, the

Tax Policy is ineffective in reducing gross soil loss in the Atlantic and South Central regions. On the other hand, the 5 Ton Limit's restriction on gross soil loss forces soil conservancy practices regardless of productivity and profitability. As a result, gross soil loss is lower than under the Tax Policy used. However, as mentioned previously a higher penalty under the Tax Policy could be as restrictive as the 5 Ton Limit. Subsequent studies will be devoted to analysis of tax and subsidy levels which might cause soil loss per acre or river sedimentation to decline to various target levels.

Conservation and Tillage Practices

Conservation and tillage practices are two important variables which determine the quantity of gross soil loss and, therefore, the levels of sediment. This section focuses on (a) the patterns of conservation and tillage practices generated under the Base solutions and (b) the changes in these patterns resulting from the use of the policy alternatives. The national distribution of conservation and tillage practices are first compared among all solutions, then similar comparisons are made for the reporting regions.

National conservation and tillage practices

Base solution National conservation and tillage practices are only slightly altered between the low and the high export Base (Tables 8 and 9). Contouring and straight row cropping are the dominant conservation practices, despite slight reductions in both under the high export Base. The reduction in these soil conserving practices is caused by greater commodity prices under the high export Base which make terracing more attractive.

Table 8. The national percentage distribution of land management practices for all solutions

Item	Low Export			High Export		
	Base	Tax Policy	5 Ton Limit	Base	Tax Policy	5 Ton Limit
Straight row	34.6	28.6	25.2	33.5	26.6	24.4
Contouring	49.4	51.0	52.8	46.4	48.5	50.6
Strip cropping	8.6	5.6	5.8	9.0	5.6	4.6
Terracing	7.4	14.8	16.2	11.1	19.3	20.4

Table 9. The national percentage distribution of tillage practices for all solutions

Item	Low Export			High Export		
	Base	Tax Policy	5 Ton Limit	Base	Tax Policy	5 Ton Limit
Con RR[a]	17.1	15.1	15.6	17.5	14.9	17.6
Con RL[b]	48.8	44.6	38.2	47.8	44.8	33.9
Minimum tillage	34.1	40.3	46.2	34.7	40.3	48.5

[a]Conventional tillage, residue removed.

[b]Conventional tillage, residue left.

Tax Policy solution   Both policy alternatives involve indirect costs on soil loss. As a result, better soil conservation and tillage practices are used relative to the Base. The national percentage of straight row and strip cropping decreases while increases in contouring and terracing occur (Table 8). Similarly, tillage practices show shifts toward minimum tillage and away from conventional tillage systems (Table 9).

The above shifts in national soil conservation practices are more pronounced under the 5 Ton Limit than under the Tax Policy. For reasons previously mentioned, this effect is very different in the erosive and more productive North Atlantic, South Atlantic, and South Central regions.

North Central, Northwest and Southwest regions and conservation and tillage practices

Conservation and tillage practices in the North Central, Northwest, and Southwest regions remain essentially the same for all solutions. The policy alternatives marginally increase soil conserving practices relative to the Base in these three regions. In the Western regions, soil erosion is not a problem (average gross soil loss per acre is low, as is the marginal effect of the policy alternatives). In the North Central region, the 5 Ton Limit has little effect in encouraging soil conserving practices because the region is not very erosive (average gross soil loss under the the Base is approximately 5.0 tons). In the case of the Tax Policy, its ineffectiveness stems not only from the relatively low erosivity of the North Central region, but also because of the region's greater commodity productivity.

North Atlantic, South Atlantic, and South Central regions and conservation and tillage practices

In the above three regions, the percent of terracing marginally increases from the low to the high export Base (Table 10). The increase in terracing stems from the greater use of land classes III and IV in meeting the high export demands. Terracing increases on classes III and IV lands. The higher prices for commodities under the high export Base also make terracing more attractive.

In the case of tillage practices, the Base solution shows only a slight tendency towards minimum tillage under the high export level (Table 11). Higher commodity prices and greater use of land classes III and IV again are the factors which encourage such changes.

The policy alternatives cause better land management techniques relative to the Base in all of the above regions (Table 10). Straight row cropping declines and terracing increases substantially. The effect of the Tax Policy is not as pronounced as for the 5 Ton Limit because of the regions' relative productivity.

On tillage practices, the policy alternatives especially encouraged more minimum tillage relative to the Base. The 5 Ton Limit has a greater effect than the Tax Policy. This is particularly evident in the South Atlantic where minimum tillage increases considerably under the 5 Ton Limit in order to accommodate the endogenous soil loss restriction (Table 11).

Table 10. The percentage distributions of land practices for all solutions in the North Atlantic, South Atlantic, and South Central regions

Item	Low Export			High Export		
	Base	Tax Policy	5 Ton Limit	Base	Tax Policy	5 Ton Limit
			North Atlantic			
Straight row	31.1	18.4	14.1	26.2	19.8	16.5
Contouring	60.2	60.6	60.9	57.4	58.8	59.6
Strip cropping	7.6	12.0	12.2	7.8	12.7	11.4
Terracing	1.1	9.0	12.8	8.6	8.7	12.5
			South Atlantic			
Straight row	41.2	40.6	39.6	42.2	37.6	28.9
Contouring	47.7	45.5	47.2	44.6	47.2	55.6
Strip cropping	9.2	6.4	1.2	8.7	5.6	1.7
Terracing	1.9	7.5	12.0	4.5	9.6	13.8
			South Central			
Straight row	49.2	37.3	22.0	45.9	32.3	21.4
Contouring	28.1	34.6	50.4	25.9	34.9	47.4
Strip cropping	----	1.3	1.4	----	1.2	----
Terracing	22.7	26.8	26.2	28.2	31.6	31.2

Table 11. The North Atlantic, South Atlantic, and South Central percentage distributions of tillage practices for all solutions

Item	Low Export Base	Low Export Tax Policy	Low Export 5 Ton Limit	High Export Base	High Export Tax Policy	High Export 5 Ton Limit
			North Atlantic			
Con RR[a]	14.6	12.3	11.5	14.1	13.1	14.1
Con RL	34.2	26.4	27.9	28.6	43.4	28.8
Minimum tillage	51.2	61.3	60.6	57.3	43.4	57.1
			South Atlantic			
Con RR	4.7	4.3	8.6	3.5	3.1	5.7
Con RL	85.6	83.2	18.2	84.9	80.2	21.1
Minimum tillage	9.7	12.5	73.2	11.6	16.7	73.2
			South Central			
Con RR	28.2	29.2	25.8	28.2	28.7	29.9
Con RL	71.8	69.1	65.6	70.3	66.4	56.9
Minimum tillage	----	1.7	8.6	1.5	4.9	13.2

[a]Con RR = conservation with residue removed and Con RL = conservation with residue left.

Great Plains conservation and tillage practices

The high export Base causes marginal increases in soil conserving practices relative to the low export Base in the Great Plains. These increases occur because yields are somewhat higher under the conservation practices and are profitable under high export demands. The percentages of terracing and minimum tillage increase under the high export Base (Tables 12 and 13) as these practices become less expensive to other practices in commodity production.

With the policy solutions, the shifts to more soil conserving practices are further enhanced because of the cost attached to them by soil loss. However, unlike the other regions, the Tax Policy is more effective than the 5 Ton Limit in inducing soil conserving practices. Relatively lower regional productivity coupled with low erosion rates act to make the Tax Policy more effective in the Great Plains. The 5 Ton Limit is met on many land classes under the low erosion rates of even the Base solutions. However, the Tax Policy causes even these low rates of erosion to be unprofitable.

National and Regional Changes in Cropping Patterns

Changes in crop production and acreage are the main variables considered in delineating differences in cropping patterns. Changes in these two variables determine variations in crop yields, thus, the latter is excluded. First, cropping patterns in the two Base solutions are compared; then, given a Base, similar comparisons are made for the policy alternatives.

Table 12. The Great Plains percentage distribution of land management practices for all solutions

Item	Low Export Base	Low Export Tax Policy	Low Export 5 Ton Limit	High Export Base	High Export Tax Policy	High Export 5 Ton Limit
Straight row	21.5	14.0	12.9	21.6	12.3	13.8
Contouring	51.1	53.0	49.1	45.3	45.6	43.9
Strip cropping	12.0	3.7	5.8	12.6	4.8	5.1
Terracing	15.4	29.3	32.2	20.5	37.3	37.2

Table 13. The Great Plains percentage distribution of tillage practices for all solutions

Item	Low Export Base	Low Export Tax Policy	Low Export 5 Ton Limit	High Export Base	High Export Tax Policy	High Export 5 Ton Limit
Con RR	20.0	11.8	13.9	19.0	8.5	13.1
Con RL	72.8	63.1	69.2	67.9	61.7	57.5
Minimum tillage	7.2	25.1	16.9	13.1	29.8	29.5

The national cropping patterns

Base solutions   The greater commodity requirement at the high export level is clearly reflected in the national cropping patterns of the high export Base solution. Relative to the low export Base, the production of row crops increases (Table 14) despite substitution in the livestock sector away from corn grain and oilmeals. The general increase in production forces greater use of marginal lands which account for the large increase in crop acres (Table 15) and the general decline in crop yields (Table 16).

Policy solutions   The policy alternatives cause a decline in row crop production relative to the Base solutions. At the low export level, both policies generate a decline in all row crop production; hay is substituted for silage, and rotations of small grains and hay are increased in order to reduce soil loss. With the low export Tax Policy solution row crops are produced intensively, and a decline in production materializes on less productive land classes. This causes total crop acres to fall relative to the Base (Table 15) and row crop yields to increase generally (Table 16). The low export 5 Ton Limit policy, on the other hand, produces row crops more extensively, and small grains rather than hay is used to compensate for soil loss. As a result, crop yields fall generally with respect to the Base (Table 16).

The high export Tax Policy solution has effects on cropping patterns which are similar to its low export counterpart. However, the greater demand for commodities at the high export level forces production onto less productive land classes. This shift in production dampens increases

Table 14. National endogenous crop production for all solutions (million units)

Crop	Unit	Low Export			High Export		
		Base	Tax Policy	5 Ton Limit	Base	Tax Policy	5 Ton Limit
Barley	Bu	554	587	701	448	503	417
Oats	Bu	339	317	502	261	305	326
Wheat	Bu	1,900	1,900	2,084	1,926	1,918	1,935
Corn grain	Bu	6,436	6,645	6,042	6,188	6,407	6,558
Sorghum grain	Bu	798	577	876	944	677	636
Silages[a]	Tons	464	391	352	455	375	306
Soybean	Bu	2,974	2,928	2,873	3,714	3,662	3,600
Cotton	Bale	11	11	11	11	11	11
Hays[b]	Tons	271	298	315	278	308	332

[a]Silages include corn and sorghum.

[b]Hays include legume and nonlegume hay, but not pasture.

Table 15. The national distribution of endogenous acres by crop for all solutions (000 acres)

Item	Low Export			High Export		
	Base	Tax Policy	5 Ton Limit	Base	Tax Policy	5 Ton Limit
Small grains	68,319	69,330	80,466	72,415	72,980	65,077
Corn and sorghum grains	74,111	72,317	72,525	76,070	71,836	84,475
Silages	31,703	26,230	25,459	32,500	26,725	25,949
Soybean	88,895	85,751	86,120	111,407	108,580	110,052
Hays	35,013	44,140	48,268	38,624	48,574	57,055
Cotton	7,406	7,097	7,401	7,154	6,962	8,055
Other[a]	23,514	17,461	13,482	15,198	13,073	7,699
Total[b]	328,961	322,326	333,721	353,368	348,730	358,362

[a]This includes land in fallow and sugarbeets.

[b]Total may not add because of computer rounding.

Table 16. National crop yields for all solutions

Commodities	Unit	Low Export			High Export		
		Base	Tax Policy	5 Ton Limit	Base	Tax Policy	5 Ton Limit
Barley	Bu	55.56	57.72	52.90	56.76	55.58	66.50
Oats	Bu	68.49	65.02	63.55	62.24	59.16	62.11
Wheat	Bu	35.58	35.00	35.12	32.29	32.62	36.14
Corn grain	Bu	107.92	107.12	107.16	108.59	108.07	90.24
Sorghum grain	Bu	55.12	56.10	54.25	49.45	53.92	53.84
Corn silage	Tons	14.97	16.12	15.42	14.89	15.17	12.89
Sorghum silage	Tons	14.51	14.48	13.08	13.61	13.48	11.03
Soybean	Bu	33.47	34.15	33.36	33.34	33.73	32.71
Cotton	Bales	1.48	1.55	1.48	1.53	1.58	1.36
Nonlegume hay[a]	Tons	13.74	10.72	9.78	13.03	9.90	7.57
Legume hay	Tons	4.26	4.14	4.22	4.02	4.01	4.14

[a]Nonlegume hay does not include pasture.

in crop yields. The 5 Ton Limit policy differs considerably at the high export level. Small grains are produced intensively on the more productive land classes; the production of corn grain is increased, and hay rather than small grains is used to compensate for soil loss on the less productive land classes. Furthermore, both the land-using phenomenon of the 5 Ton Limit policy and the high export's greater commodity requirements act to reduce crop yields considerably compared to the Base. Small grain yields are the only definite exception (Table 16) because production on less productive land classes falls as hay rotations are increased.

The North Atlantic cropping patterns

Base solutions Increasing exports under the Base solutions causes a switch rather than an increase in the North Atlantic's cropping pattern. Total acreage increases only marginally (Table 18) because land is almost fully utilized. Crop production switches towards more corn grain, soybean and hays, and away from small grains (Table 17). The shifts in crop production follow the change in export demand at the high export level.

Policy solutions The policy solutions have varied effects on the North Atlantic's cropping pattern depending on the export level. At the low export level both policies cause shifts to less erosive crops. The production and acreage of small grains and hays increase while the opposite changes are observed for row crops (Tables 17 and 18). This effect stems from the higher cost of soil loss under the policy solutions which increases the profitability of less erosive crops. At the high

Table 17. The North Atlantic endogenous crop production for all solutions (million units)

Crop	Unit	Low Export			High Export		
		Base	Tax Policy	5 Ton Limit	Base	Tax Policy	5 Ton Limit
Barley	Bu	64	64	64	64	64	64
Oats	Bu	19	9	8	7	8	38
Wheat	Bu	175	187	192	166	122	61
Corn grain	Bu	396	376	338	486	463	402
Silages[a]	Tons	13	11	11	11	11	14
Soybean	Bu	8	7	12	11	42	42
Hays[b]	Tons	10	11	11	11	11	14

[a]Silages include corn and sorghum.

[b]Hays include legume and nonlegume hay, but not pasture.

Table 18. The North Atlantic distribution of endogenous acres by cost for all solutions (000 acres)

Item	Low Export			High Export		
	Base	Tax Policy	5 Ton Limit	Base	Tax Policy	5 Ton Limit
Small grains	5,098	5,125	5,241	4,571	3,656	2,814
Corn and sorghum grain	3,661	3,446	3,150	4,397	4,202	3,819
Silages	689	577	629	636	620	805
Soybean	208	183	323	275	1,182	1,152
Hays	1,639	1,963	1,878	1,981	1,981	2,883
TOTAL[a]	11,295	11,295	11,219	11,859	11,640	11,473

[a]Total may not add because of computer rounding.

export level, however, the profitability of row crops increases relative to the cost on soil loss. As a result, soybean production under both policies increases fourfold, and small grains and hay acreages decline.

The effects of the export levels are more dramatic under the 5 Ton Limit than under the Tax Policy. The difference stems from the restriction on soil loss under the 5 Ton Limit policy which alters crop production to insure its endogenous soil requirement before considering crop profitability.

South Atlantic cropping patterns

Base solutions The South Atlantic crop acreages increase by two million acres from the low to the high export Base (Table 20). The change in acreage follows the shift in export demand which causes a 12 percent increase in soybean production under the high export Base (Table 19).

Policy solutions With the policy alternatives, the induced cost on soil loss encourages substitution away from the more erosive row crops. Increases in the production and acreages of small grains, hays and corn grain occur, while production of soybeans and, to a lesser extent, cotton declines. The 5 Ton Limit has a greater impact in making these adjustments because of (a) its endogenous soil loss requirement and (b) the relatively greater productivity of the South Atlantic region which dampens drastic adjustments by the Tax Policy.

North Central cropping patterns

Base solutions The high export Base has a 4.3 million acre increase in land use in the North Central region relative to the low

Table 19. The South Atlantic endogenous crop production for all solutions (milion units)

Crop	Unit	Low Export			High Export		
		Base	Tax Policy	5 Ton Limit	Base	Tax Policy	5 Ton Limit
Barley	Bu	24	24	48	24	24	26
Oats	Bu	13	2	117	13	2	47
Wheat	Bu	33	84	201	39	72	344
Corn grain	Bu	74	80	293	63	92	318
Sorghum grain	Bu	22	-	-	-	-	-
Silages[a]	Tons	18	23	26	19	19	15
Soybean	Bu	855	687	416	959	782	586
Cotton	Bales	8.7	9.0	8.2	8.9	9.0	2.3
Hays[b]	Tons	28	35	36	26	35	36

[a]Silages include corn and sorghum.

[b]Hays include legume and nonlegume hay, but not pasture.

Table 20. The South Atlantic distribution of endogenous acres by crop for all solutions (000 acres)

Item	Low Export			High Export		
	Base	Tax Policy	5 Ton Limit	Base	Tax Policy	5 Ton Limit
Small grains	1,364	2,512	7,919	1,676	2,218	9,934
Corn and sorghum grain	994	911	4,135	718	1,248	4,944
Silages	1,192	1,535	1,844	1,271	1,251	1,128
Soybean	28,297	22,202	14,027	31,834	25,257	19,881
Hays	1,235	3,822	4,062	634	4,040	3,658
Cotton	5,861	5,952	5,364	5,839	5,835	1,537
TOTAL[a]	38,943	36,933	37,350	41,970	39,846	41,079

[a]Total may not add because of computer rounding.

export Base (Table 22). Increases in soybean and silage production (Table 21) account for the major changes in acreage as the cropping pattern adjusts to the high export deamnd. The greater production of soybeans also causes substitution among crops in land use. Small grains and hays, in particular, are forced on marginal lands as soybean production increases.

Policy solutions The policy alternatives have different effects on cropping patterns depending on the export level. At the low export level, substitution among row crops occur. Corn and sorghum grains and silages decline and production of soybeans increases relative to the Base (Table 21). Production of the less erosive crops, namely, small grains and hays also increase under the policy alternatives. At the high export level, both policies tend to reduce all row crops, and rotations of less erosive hay are increased to lower soil loss.

The main distinction between the two policies at the low export level is in their effects on small grains and silage. The 5 Ton Limit's soil loss restriction causes greater acreage of small grains relative to the Tax Policy. With silage, the 5 Ton Limit's acreage and production decline by 50 percent compared to the Tax Policy's minimal reduction.

At the high export level, the main distinction between the two policies is in their effects on small grains and hay. The 5 Ton Limit produces row crop extensively and uses more hay rather than small grains rotations to accommodate the soil loss restriction. As a result, hay production and acreage increase considerably and small grain production and acreage decline (Tables 21 and 22). The Tax Policy, on the other hand, increases both hay and small grains rotations.

Table 21. The North Central endogenous crop production for all solutions (million units)

Crop	Unit	Low Export Base	Low Export Tax Policy	Low Export 5 Ton Limit	High Export Base	High Export Tax Policy	High Export 5 Ton Limit
Barley	Bu	165	132	264	109	109	90
Oats	Bu	86	78	84	59	51	121
Wheat	Bu	537	597	749	565	614	446
Corn grain	Bu	5,561	5,284	4,923	4,808	4,611	4,682
Sorghum grain	Bu	16	20	15	57	18	9
Silages[a]	Tons	14	13	7	24	20	21
Soybean	Bu	1,774	1,901	1,887	2,195	2,262	2,128
Hays[b]	Tons	41	43	43	38	39	59

[a]Silages include corn and sorghum.

[b]Hays include legume and nonlegume hay, but not pasture.

Table 22. The North Central distribution of endogenous acres by crop for all solutions (000 acres)

Item	Low Export			High Export		
	Base	Tax Policy	5 Ton Limit	Base	Tax Policy	5 Ton Limit
Small grain	21,766	23,151	30,326	23,010	24,326	13,470
Corn and sorghum grain	51,742	48,881	45,251	45,738	42,766	51,354
Silages	869	809	424	2,199	1,943	2,289
Soybean	49,326	52,971	53,389	61,660	63,426	60,904
Hays	5,497	5,220	5,110	3,862	4,169	10,897
Others[a]	4,422	3,478	1,224	1,479	1,284	717
TOTAL[b]	133,622	134,510	135,724	137,948	137,914	139,631

[a]This includes land in fallow and sugarbeets.

[b]Total may not add because of computer rounding.

The South Central cropping patterns

Base solutions The high export Base solution increases the less erosive small grains and hays relative to the low export Base. On the other hand, row crop production remains relatively unchanged except for a 17 percent increase in soybean and a 6 percent decline in grain sorghum (Table 23).

Policy solutions The policy solutions generally act to reduce row crop production and to increase production and acreage of small grains and hays relative to the Base solutions. The low export policy alternatives result in a decline in the production of all row crops relative to the Base, and increases the acreage and production of small grains and hays. However, at the high export level soybean production is encouraged (Tables 23 and 24).

The main impacts between the two policies on cropping patterns are in their effects on small grains at the high export level, and on cotton regardless of the export level. The high export 5 Ton Limit causes a decline in the production and acreage of small grains relative to the high export Base solution: the high export Tax Policy has the opposite result. The 5 Ton Limit's effect is transmitted through the increased comparative advantage of soybeans. As soybean acreage increases, the less erosive hay is substituted for small grains to accommodate the soil loss restriction. This causes the extensive production of hay and soybeans, and intensive production of small grains. With the Tax Policy, there is no soil loss restriction and substitution is limited. On cotton, the 5 Ton Limit shifts production considerably from the South

Table 23. The South Central endogenous crop production for all solutions (million units)

Crop	Unit	Low Export			High Export		
		Base	Tax Policy	5 Ton Limit	Base	Tax Policy	5 Ton Limit
Barley	Bu	42	48	51	26	32	60
Oats	Bu	28	24	73	37	47	73
Wheat	Bu	208	254	240	270	284	165
Corn grain	Bu	169	198	66	161	151	42
Sorghum grain	Bu	459	396	264	431	319	286
Silages[a]	Tons	218	208	171	220	207	151
Soybean	Bu	115	113	87	135	180	280
Cotton	Bales	1.5	1.0	1.5	1.1	0.9	3.6
Hays[b]	Tons	95	94	121	104	108	112

[a]Silages include corn and sorghum.

[b]Hays include legume and nonlegume hay, but not pasture.

Table 24. The South Central distribution of endogenous acres by crop for all solutions (000 acres)

Item	Low Export			High Export		
	Base	Tax Policy	5 Ton Limit	Base	Tax Policy	5 Ton Limit
Small grain	8,600	10,083	10,668	11,000	11,916	8,059
Corn and sorghum grains	11,082	9,263	5,409	9,963	6,737	4,647
Silages	16,837	15,865	14,414	17,828	16,369	14,311
Soybean	3,792	3,672	3,413	4,523	6,375	10,601
Hays	13,726	13,791	21,784	17,104	18,877	20,300
Cotton	1,175	717	1,478	892	452	2,369
Others[a]	1,223	1,510	281	454	410	2,143
TOTAL[b]	56,435	54,901	57,447	61,764	61,135	62,430

[a]This includes land in fallow and sugarbeets.

[b]Total may not add because of computer rounding.

Atlantic region to the South Central and Southwest regions. The Tax Policy tends to switch production away from the South Central region. The Tax Policy's regional changes in cotton production is a direct reflection of the relationship between the tax on sediment and regional productivity. The 5 Ton Limit's effect stems from the greater erosivity of the South Atlantic relative to the South Central. This erosivity difference and the soil loss requirement of the 5 Ton Limit causes the switch in cotton production from the South Atlantic to the South Central region.

The Great Plains cropping patterns

Base solutions Total crop acreage in the Great Plains increases by 14 percent or 9.5 million acres between the low to the high export Base solutions (Table 26). The combined acreage of corn and sorghum grains increases by 150 percent, while soybean production and acreage increase by more than 80 percent. These large crop changes are tied to the greater demand for soybeans at the high export level. It directly influences soybean cropping patterns, and indirectly induces greater corn and sorghum grain production in the Great Plains region. The indirect effect acts through the increased production of soybeans in the North Central region. There is a shift in the regional comparative advantage of corn grain production from the North Central to the Great Plains region (i.e. a shift in the comparative advantage of soybeans in the North Central region). The greater availability of land in the Great Plains also serves to provide flexibility in greater crop production.

Policy solutions The policy solutions encourage corn grain production in the Great Plains relative to the Base solutions. The Tax Policy causes a slight reduction in soybean production and acreage; hay is substituted for silage in livestock production, and the only increase in row crops is in corn grain production (Tables 25 and 26).

The 5 Ton Limit, on the other hand, increases the comparative advantage of both corn grain and soybeans. This effect is more distinct at the low export level where production and acreage of corn and sorghum more than double. The tendency for greater row crop production under the 5 Ton Limit relative to the Base is linked to the reallocation of row crop production from the erosive South Atlantic region. The 5 Ton Limit restriction on soil loss forces the erosive row crops from the South Atlantic and the reallocation occurs in the Great Plains.

The Northwest and Southwest cropping patterns

Base solutions In the Northwest and Southwest regions the high export Base encourages greater production of row crops with little effect on small grains and hays relative to the low export Base (Tables 27 and 28). The adjustments under the high export Base follow the change in national export demand. However, the adjustments are not as dramatic as in other regions owing to the small land base and the comparative disadvantage of the Western regions in the production of endogenous crops.

Policy solutions Since the Western regions do not have great soil loss problems, the 5 Ton Limit has little direct effect in changing production relative to the Base. However, the reallocation of row crop

Table 25. The Great Plains endogenous crop production for all solutions (million units)

Crop	Unit	Low Export			High Export		
		Base	Tax Policy	5 Ton Limit	Base	Tax Policy	5 Ton Limit
Barley	Bu	205	263	222	219	234	136
Oats	Bu	189	199	215	133	186	42
Wheat	Bu	575	405	361	507	453	570
Corn grain	Bu	78	525	253	436	856	1,014
Sorghum grain	Bu	302	161	597	455	340	341
Silages[a]	Tons	157	92	95	129	68	61
Soybean	Bu	222	220	471	414	394	564
Hays[b]	Tons	22	75	63	58	75	57

[a]Silages include corn and sorghum.

[b]Hays include legume and nonlegume hay, but not pasture.

Table 26. The Great Plains distribution of endogenous acres by crop for all solutions (000 acres)

Item	Low Export			High Export		
	Base	Tax Policy	5 Ton Limit	Base	Tax Policy	5 Ton Limit
Small grains	22,401	19,075	17,815	21,960	21,147	21,486
Corn and sorghum grains	5,159	7,870	12,971	12,922	14,452	18,718
Silages	9,821	5,171	5,897	7,814	3,965	4,534
Soybean	7,270	6,721	14,967	13,112	12,338	17,512
Hays	9,085	14,496	10,180	9,897	14,559	9,528
Others[a]	12,555	9,701	8,072	10,091	8,783	6,447
Total[b]	66,291	63,034	69,902	75,796	75,244	78,225

[a]This includes land in fallow and sugarbeets.

[b]Total may not add because of computer rounding.

Table 27. The Northwest and Southwest endogenous crop production for all solutions (million units)

Crop	Unit	Low Export			High Export		
		Base	Tax Policy	5 Ton Limit	Base	Tax Policy	5 Ton Limit
				Northwest			
Barley	Bu	20	24	20	20	20	7
Oats	Bu	4	5	4	11	11	4
Wheat	Bu	295	298	258	285	275	262
Corn grain	Bu	130	152	139	203	203	90
Silages[a]	Tons	6	6	6	11	9	22
Hays[b]	Tons	9	9	11	9	9	22
				Southwest			
Barley	Bu	35	32	33	27	19	34
Wheat	Bu	77	73	82	95	98	87
Corn grain	Bu	27	31	30	31	31	9
Silages[a]	Tons	39	39	38	41	40	23
Cotton	Bales	0.9	1.0	1.3	1.0	1.1	5.1
Hays[b]	Tons	30	31	30	32	32	37

[a]Silages include corn and sorghum

[b]Hays include legume and nonlegume hay, but not pasture.

Table 28. The Northwest and Southwest distribution of endogenous acres by crop for all solutions (000 acres)

Item	Low Export			High Export		
	Base	Tax Policy	5 Ton Limit	Base	Tax Policy	5 Ton Limit
Northwest						
Small grains	6,902	7,415	6,240	7,602	7,230	6,745
Corn and sorghum grains	1,242	1,672	1,343	2,059	2,160	908
Silages	345	345	349	761	606	1,686
Soybean	-	-	-	-	-	-
Hays	1,189	1,153	1,671	1,206	982	5,325
Others[a]	3,547	2,163	3,145	2,234	1,966	47
TOTAL[b]	13,225	12,748	12,748	13,880	12,944	14,711
Southwest						
Small grains	2,179	1,961	2,249	2,573	2,480	2,559
Corn and sorghum grains	228	268	261	268	268	87
Silages	1,943	1,921	1,898	1,986	1,968	1,193
Soybean	-	-	-	-	-	-
Hays	3,594	3,689	3,558	3,936	3,949	4,459
Cotton	396	427	557	422	452	2,369
Others[a]	783	619	781	879	868	125
TOTAL[b]	9,096	8,885	9,304	10,064	9,985	10,792

[a]This includes land in fallow and sugar beets.
[b]Total may not add because of computer rounding.

production from erosive regions to the western regions occurs. For example, cotton production switches considerably from the South Atlantic region to the Southwest region under the 5 Ton Limit (Table 27).

The Tax Policy, unlike the 5 Ton Limit, has a cost on soil loss in the western regions. Although this cost is small, it serves to encourage greater production of less erosive crops and dampens increases in row crops. This effect is seen on cotton production in the Southwest region and on small grains in the Northwest region.

National Endogenous Livestock Feed Use

The high export Base solution does not alter national livestock feed use relative to the low export Base. Feed grains are altered little in total quantity, although sorghum is substituted for corn. Small grains and oilmeals decline marginally. The roughage mix remains relatively unchanged with limited substitution of hays for silage (Table 29).

Because of the higher cost on soil loss under the Tax Policy and 5 Ton Limit, row crops become costly. As a result, the use of corn in livestock feeds declines relative to the Base solutions (Table 29). However, the two policies differ on the mix; the Tax Policy favors corn while the 5 Ton Limit favors grain sorghum. Also, the 5 Ton Limit has greater effect in altering ration compositions relative to the Base solutions. It decreases the importance of small grains and substitutes hay for livestock, partly because it shifts some emphasis on feed

Table 29. Total endogenous crop use in the livestock sector for all solutions (million units)

Crop	Unit	Low Export			High Export		
		Base	Tax Policy	5-Ton Limit	Base	Tax Policy	5-Ton Limit
Corn grain	Bu	4,023	4,233	3,630	3,790	4,009	4,159
Sorghum grain	Bu	516	295	593	644	377	336
Barley	Bu	344	376	491	278	292	207
Oats	Bu	228	207	391	150	195	216
Wheat	Bu	63	63	247	131	123	141
Silages[a]	Tons	464	391	352	455	375	306
Oilmeals	Cwt	746	724	698	731	707	677
Hays[b]	Tons	271	298	315	278	313	332

[a]Silages include corn and sorghum.

[b]Hays include legume and nonlegume hay, but not pasture.

grains from corn in the North Central region to grain sorghum in the Great Plains regions.

Resources Used in Crop Production

The effects of the several alternatives on use of land, nitrogen and pesticides are reviewed in this section. In general, the 5 Ton Limit tends to "tighten up" the supply of land available to crops.

Land use

Table 30 includes percents of the total cropland base used by crops under the several solutions. At the national level the percentage utilization increases for the Base solutions from 89.6 under low exports to 95.8 under high exports. A somewhat similar pattern is followed in the various regions.

Because the 5 Ton Limit causes shifts of some row crops from hilly land, with the area taken over by small grains and hay, total land use tends to be highest under this policy. However, the difference is small compared to the Base and Tax Policy solutions.

Nitrogen and pesticide use

Although there is some variation by regions, more nitrogen and pesticides generally are used under high exports as compared to low exports. The general increase at the national level results from a greater

Table 30. Percentage utilization of total cropland (exogenous and endogenous) by regions under the low and high export solutions

Item	The Demand Alternatives	
	Low Export	High Export
	North Atlantic	
Base	94.5	98.7
Tax Policy	94.5	97.0
5 Ton Limit	94.0	95.8
	South Atlantic	
Base	90.3	96.4
Tax Policy	86.3	92.1
5 Ton Limit	87.1	94.6
	North Central	
Base	94.1	97.0
Tax Policy	94.8	97.1
5 Ton Limit	95.6	98.2
	South Central	
Base	89.4	97.4
Tax Policy	87.0	96.5
5 Ton Limit	90.0	98.4
	Great Plains	
Base	81.3	92.6
Tax Policy	77.4	91.9
5 Ton Limit	85.6	95.5
	Northwest	
Base	89.0	92.6
Tax Policy	86.1	87.2
5 Ton Limit	86.1	97.4
	Southwest	
Base	85.7	92.3
Tax Policy	84.3	94.6
5 Ton Limit	87.1	97.1
	United States	
Base	89.6	95.8
Tax Policy	87.9	94.6
5 Ton Limit	90.8	97.1

acreage of crops needed to supply the greater export level and the fact that the overall crop mix uses greater per acre quantities of these inputs. Imposition of the Tax Policy or the 5 Ton Limit causes fertilizer and nitrogen use to vary by region as compared to the Base solutions. The two policies cause row cropping to move out of some regions and into others. Use of the two inputs is changed accordingly.

At the national level, the Tax Policy uses only slightly more nitrogen than the Base. However, the Tax Policy uses considerably more pesticides than does the Base solution because of a greater acreage of minimum tillage and related shifts. The 5 Ton Limit uses considerably more of both nitrogen and pesticides than does the Tax Policy and the Base solutions (Tables 31 and 32). The 5 Ton Limit has a somewhat greater acreage to be treated than the other alternatives. Also, its crop mix calls for heavier average applications per acre of both nitrogen and pesticides. In general, the 5 Ton Limit is more resource-using than either the Base or Tax Policy alternatives.

Land Rents

Imputed values (shadow prices or rents) of land are included in Tables 33 and 34. The impact of high exports in increasing land rents through the model solutions parallel the real world outcomes in the several years after 1973 when U.S. exports increased dramatically. Land rents and prices leaped dramatically as Russia began buying large quantities of grain.

In the model solutions, land rents approximately double with high exports under the Base solution and the Tax Policy. The increase is

Table 31. Regional nitrogen use for all solutions (1000 tons)

Region	Low Export Base	Low Export Tax Policy	Low Export 5 Ton Limit	High Export Base	High Export Tax Policy	High Export 5 Ton Limit
North Atlantic	370	365	344	408	369	340
South Atlantic	668	803	1,170	667	823	1,127
North Central	3,910	3,634	3,720	3,484	3,272	3,906
South Central	1,837	1,764	1,904	1,989	1,980	1,945
Great Plains	1,195	1,534	1,543	1,657	1,920	2,192
Northwest	447	478	427	541	517	584
Southwest	484	518	534	536	545	702
United States	8,911	9,096	9,639	9,282	9,426	10,796

Table 32. Regional pesticide use for all solutions in million dollars[a]

Region	Low Export Base	Low Export Tax Policy	Low Export 5 Ton Limit	High Export Base	High Export Tax Policy	High Export 5 Ton Limit
North Atlantic	76	84	81	94	76	88
South Atlantic	171	178	407	186	206	356
North Central	944	969	972	978	987	988
South Central	36	37	128	43	80	381
Great Plains	53	302	219	197	602	656
Northwest	14	16	14	25	21	49
Southwest	10	12	17	14	16	98
United States	1,303	1,599	1,837	1,537	1,988	2,615

[a] The costs are comparable in terms of units of pesticide used since the costs are independent of shadow prices.

Table 33. Land rents (shadow prices) on dryland by regions for the various solutions (measured in 1972 dollars)

Regions	Low Export	High Export
	North Atlantic	
Base	23.45	52.26
Tax Policy	32.35	54.07
5 Ton Limit	28.37	152.99
	South Atlantic	
Base	21.60	47.89
Tax Policy	23.66	47.81
5 Ton Limit	23.92	174.71
	North Central	
Base	25.48	53.68
Tax Policy	29.43	54.11
5 Ton Limit	35.23	212.14
	South Central	
Base	17.12	30.93
Tax Policy	18.29	30.49
5 Ton Limit	18.23	74.81
	Great Plains	
Base	10.94	23.92
Tax Policy	10.66	22.73
5 Ton Limit	14.88	114.88
	Northwest	
Base	12.55	19.80
Tax Policy	11.53	21.53
5 Ton Limit	15.00	75.16
	Southwest	
Base	5.52	7.43
Tax Policy	6.30	8.59
5 Ton Limit	8.02	46.28
	United States	
Base	20.41	41.66
Tax Policy	22.85	42.58
5 Ton Limit	25.91	162.51

Table 34. Land rents (shadow prices) on irrigated land by regions for the various solutions (measured in 1972 dollars)

Regions	Low Export	High Export
	South Central	
Base	87.25	127.11
Tax Policy	90.14	123.07
5 Ton Limit	72.16	239.27
	Great Plains	
Base	62.22	94.51
Tax Policy	58.65	92.43
5 Ton Limit	60.16	225.76
	Northwest	
Base	31.03	49.98
Tax Policy	34.85	54.11
5 Ton Limit	36.30	155.66
	Southwest	
Base	39.29	64.86
Tax Policy	44.41	64.81
5 Ton Limit	48.97	209.36
	United States	
Base	57.72	87.60
Tax Policy	59.70	86.58
5 Ton Limit	55.85	212.70

several times under the 5 Ton Limit, with the relative impact being greater for irrigated than for dryland. However, neither the Tax Policy nor the 5 Ton Limit cause much change in land rents, as compared to the Base, when exports are at the low level.

Land use has greater flexibility under the Tax Policy than under the 5 Ton Limit. Under the 5 Ton Limit each land class in each producing area must reduce soil loss below five tons per year. Under the Tax Policy some soil classes and regions can have more soil loss while others have less. Hence, land is relatively more scarce for row cropping under the 5 Ton Limit. Also, more row cropped feed grains move out of the dryland farming areas susceptible to erosion and onto irrigated lands where there is less danger of erosion. Hence, not only are all land rents high for the 5 Ton Limit at high exports but they are especially high for irrigated land.

Shadow Prices for Endogenous Commodities

Relative shadow prices for commodities and per capita food costs are included in Table 35 for commodities which are endogenous to the model. Imposition of the Tax Policy or the 5 Ton Limit has only slight effects on prices when exports are at low levels. However, high exports cause commodity shadow prices to increase over low exports under all solutions. The increase is greatest for the 5 Ton Limit. The reasons for the greater price increase under the latter case again are those explained above for increases in land rents.

Table 35. Indices of shadow prices for the endogenous commodities, and average food cost of endogenous crops per capita for all solutions (the low export base = 100)

Item	Unit	Low Export			High Export		
		Base	Tax Policy	5 Ton Limit	Base	Tax Policy	5 Ton Limit
Barley	Bu	100	107	107	130	140	274
Oats	Bu	100	107	119	144	137	278
Wheat	Bu	100	110	108	135	141	254
Corn grain	Bu	100	109	104	128	133	204
Sorghum grain	Bu	100	110	100	127	133	229
Oilmeals	Cwt	100	115	129	136	151	445
Cotton	Bale	100	104	109	115	116	184
Silages[a]	Ton	100	105	105	122	123	196
Legume hay	Ton	100	104	106	124	127	248
Nonlegume hay	Ton	100	106	107	128	131	248
Pork	Cwt	100	106	106	116	120	196
Milk	Cwt	100	103	102	108	110	141
Beef feeders	Head	100	103	104	116	116	185
Fed beef	Cwt	100	104	105	116	117	189
Nonfed beef	Cwt	100	104	105	116	117	189
Food cost per capita		100	104	105	116	118	190

[a]Silages include corn and sorghum.

IV. LIMITATIONS

The linear programming model used is normative in nature. Hence, it best predicts potentials for the future which are consistent with the resource, technological, and institutional restraints incorporated. The model is not predictive of farmers' expected behavior. However, if the potentials unveiled in the study should prove to have social preference, policies could be devised to cause farmers' responses to approximate the potentials revealed by the study.

Since the model does not attempt to reflect decision procedures of farmers, the results of the study need to be viewed in terms of the long run when forces which dampen farmers' decisions and actions can be relaxed. As stated before, of course, this study is concerned more with potentials in resource use than with the farmer decision process. There is need for an in-depth examination of farmers' decision processes relating to adoption of soil conservation measures. Also, these differences also might better be resolved in further studies which incorporate multiple goals in the linear programming model.

The structure of the model mainly (although not entirely) causes particular land classes in individual producing areas to shift entirely from one practice (e.g. conventional up-and-down-the-hill row cropping or residual removal) to another practice (e.g. contour farming or residuals retained). In the actual world, however, all farmers on one land class are not likely to shift simultaneously from one discrete practice to another in lock-step fashion. Even if all have the same discount rates for future returns and similar prospects for profitability, other factors can cause some to hesitate and for the adjustment to be of a distributed lag nature. While distributed lags can be modeled in linear programming frameworks, this procedure was not employed because of the long-run nature of the study. We assumed, for the time the analysis was started in 1975, that a major portion of the adjustment could be made in 10 years. This outlook may be overly optimistic, however, even under the implementation of tax, subsidy, or mandate policies which could encourage it, full adjustment could take longer.

It was not the purpose of this study to incorporate flexibility restraints which condition farmers' response to environmental goals. This step was implemented in a previous analysis of sedimentation and the environment [12]. It is being applied in a new study underway which links a linear programming model of the type included here with a time series simulation model. The linked model restrains the rate at and extent to which farmers adjust their conservation and farming practices. The large and complex study will not be completed for some time. However, when it is complete, it can be used to eliminate or lessen the impacts of this study's limitations relating to the timing and extent of adjustment.

This study assumes some yield advantages for conservation farming systems. Hence, the results should be considered long-run in nature or relate to an extended time period so that these yield differences can be reflected. While the target date used to allow a reasonable period for adjustment is 1985, it is possible that the date is too early to allow the yield differentials of the erosion control farming systems to be realized. In this sense, the target date might better have been 2000.

Large amounts of data are required for a study of this nature. The data have been extended and refined over a period of years and appear to be the best currently available. In the future, however, the data need to be refined by updating the land base (a procedure now underway) and evaluating statistical trends in crop yields (i.e. are they in prospect of plateauing, will they continue to increase but at a dampened rate, etc.). Also, it is possible that rising energy prices may cause reductions in use of nitrogen fertilizer and pesticides. These inputs are interrelated to land use, erosion control, conservation methods and tillage practices. The extent to which energy prices rise and interact with other parameters is not yet known. While models are underway to measure some of these energy impacts, studies of the current nature may need to be repeated for reevaluation as energy prices or other phenomena depart markedly from the assumptions used in this study.

IV. SUMMARY

This study analyzes potential changes in soil loss, land use, crop production, production costs, and commodity prices under several solutions relating to export levels and soil conservation policies. A national and interregional linear programming model (Base solution) first is used to estimate soil loss, land use, interregional crop production patterns, and related items under both low and high export levels for U.S. farm commodities. The same items were then estimated for two policies designed to reduce gross soil erosion and stream sedimentation. The two policies were: (a) a physical limit of 5 tons per acre of gross annual soil loss for all crop production activities (5 Ton Limit), and (b) a tax on sediment actually reaching the mainstreams (Tax Policy) which generated the same national mainstream sediment loads as the 5 Ton Limit.

Under the Base solution, estimated sedimentation increases by 14.5 percent between the low and high export levels. The national pattern of crop production and tillage practices changes only slightly between the two export levels.

The national sediment load is lower under both the Tax Policy and the 5 Ton Limit than under the Base solution. Too, the reduction in sediment load is about the same for the two policies. Regionally, the Tax Policy was more effective than the 5 Ton Limit in reducing sediment in the Great Plains and to a lesser extent, in other western regions. One reason for this was the relative ease of introduction of reduced tillage systems in these regions under the Tax Policy. For gross soil loss, however, there was a large diversity between the two policies. Overall, the Tax Policy was less effective in reducing gross soil loss. The smaller effectiveness was due to the fact that the high yields in the Atlantic and South Central regions, high erosive regions, served to dampen the effect of the tax in inducing soil conserving practices. The 5 Ton Limit policy, on the other hand, resulted in large shifts toward soil conserving practices (minimum tillage, in particular) and away from row crop production. It required compliance with the 5 Ton Limit in all producing areas and on all land classes while the Tax Policy did not.

Under the Base solution land used for crops increased from 89.6 percent of the total cropland base under low exports to 95.8 percent under high exports. Use of nitrogen fertilizer and pesticides also increased under high exports.

Relative to the Base Solution, the 5 Ton Limit proved to be land-using, while the Tax Policy was land-saving. This difference stems from the mechanisms of the two policies. The tax on sediment under the Tax Policy is an indirect cost of using land. The 5 Ton Limit, however, spreads production over a greater land area. Some land in high rainfall regions with high yields is very erosive. To meet the 5 ton restriction, this land must be farmed less intensively and production must move to areas of lower rainfall and yields.

Both policies use a greater amount of nitrogen and pesticides than does the Base solution. The land-using nature of the 5 Ton Limit policy, coupled with its greater utilization of reduced tillage, causes it to use more nitrogen and pesticides than does the Tax Policy, especially at the high export level.

Land rents increased markedly between the low and high export levels as utilization of the total land has increased. The national average under the Base solution increased by 104.1 percent for dryland and 51.7 percent for irrigated land. National average rents increased under both the Tax Policy and 5 Ton Limit. However, the increase was consistently high for the latter. Increases in land rents under the Tax Policy are restrained since it more directly acts to increase the cost of using land.

Commodity shadow prices rose between the low and high export levels for all the solutions examined. The Tax Policy and the 5 Ton Limit both caused a small increase in shadow prices at the low export level relative to the Base solution. Increases in shadow prices between the low and high export levels was about the same for the Base solutions and the Tax Policy. The 5 Ton Limit had a much larger increase in shadow prices at the high export level. The greater increase was due to the land-using characteristics of the latter policy and the movement of more of the crop production to lower yielding land classes.

Commodity shadow prices for the Base solution increased considerably between the low and high export levels. Commodity prices for the Tax Policy were slightly greater than for the Base solution at the high export level. The 5 Ton Limit is accompanied by a sharp increase in shadow prices and per capita food costs at the high export level. The high prices under the 5 Ton Limit result because grain production is pushed onto a greater area of land with low yields (and low erosion hazards).

REFERENCES

1. Baumol, William T. "On Taxation and the Control of Externality." American Economic Review 62(3) (June 1972):307-322.

2. Baumol, William T. and Oats, Wallace E. "The Use of Standards and Prices for Protection of the Environment." Swedish Journal of Economics 73(1) (March 1971):42-54.

3. Beasley, R. P. Erosion and Sediment Pollution Control. Ames: Iowa State University Press, 1972.

4. Carter, D. L. "Sediment Phosphorous in Runoff from Irrigated Lands." In Proceedings of the Third Interagency Sedimentation Conference. Denver, Colorado: Sedimentation Committee, Water Resource Council, 1976.

5. Crosson, Pierre R. "Environmental Considerations in Expanding Agricultural Exports." Journal of Soil and Water Conservation 30(1) (January-February 1975):23-28.

6. Ford, Edwin C. "Upstream Flood Damages." Journal of Soil and Water Conservation 19(6) (November-December (1964):231:234.

7. Hauser, Wade R. and Timmons, John F. "Soil Erosion Control in Western Iowa: Obstacles and Remedies." Preliminary manuscript. Department of Agricultural Economics, Iowa State University, Ames, Iowa, 1978.

8. Heady, E. O.; Madsen, H. C.; Nicol, K. J.; and Hargrove, S. H. Agricultural Water Demands. National Information Service, Report No. PB 206-790, November 1971.

9. Heady, Earl O. and Timmons, John F. "U.S. Land Needs for Meeting Food and Fiber Demands." Journal of Soil and Water Conservation 30(1) (January-February 1975):15-22.

10. Hudson, Norman. Soil Conservation. Ithaca, New York: Cornell University Press, 1971.

11. Jennings, R. D. Relative Use of Feed for Livestock Including Pasture, by States. USDA Agricultural Research Services, Statistical Bulletin No. 153, February 1955.

12. Meister, A. D. and Nicol, K. J. A Documentation of the National Water Assessment Model of Regional Agricultural Production, Land and Water Use, and Environmental Interaction. Ames: Center for Agricultural and Rural Development, Iowa State University, 1975.

13. Nicol, K. J.; Heady, E. O.; and Madsen, H. C. "Models of Soil Loss, Land and Water Use, Spatial Agricultural Structure, and the Environment." Center for Agricultural and Rural Development, Iowa State University, CARD Report 49T, 1974.

14. Plott, Charles R. "Externalities and Connective Taxes." Economica 33(129) (February 1966):84-87.

15. Robinson, A. R. "Sediment, Our Greatest Polluter." In Focus on Environmental Geology, pp. 181-187. Edited by Roland Tank. New York: Oxford University Press, 1973.

16. Soth, Lauren. "Grain Surplus is Back: Time for Storage Plan." Des Moines (Iowa) Register, July 26, 1977, p. 14A.

17. Stoecker, A. "A Quadratic Programming Model of U.S. Agriculture in 1980: Theory and Applications." Unpublished Ph.D. dissertation, Iowa State University, Ames, 1974.

18. Tontz, Robert L. Foreign Agricultural Trade Policy of the United States 1977-1976. Washington, D.C.: USDA Economics Research Service, January 10, 1977.

19. U.S. Congress. Trade Act of 1974. 93rd Congress. Public Law 93-618, H.R. 10710, January 1975.

20. U.S. Congressional Records. Senate Bill 1280. Proceedings and Debates of the 95th Congress. 1st Session 123(62), April 7, 1977.

21. U.S. Department of Agriculture, Conservation Needs Inventory Committee. National Inventory of Soil and Water Conservation Needs, 1967. USDA Statistical Bulletin No. 467, January 1971.

22. U.S. Department of Agriculture, Economic Research Service. U.S. Foreign Agricultural Trade Statistical Report, Fiscal Year 1976. Supplement to Monthly FATUS, Washington, D.C., September 1976.

23. U.S. Department of Agriculture, Statistical Report Service. Unpublished Working Papers Prepared for the National Water Assessment, Washington, D.C., 1975 (undated mimeograph).

24. U.S. Department of the Interior. Use of Water on Federal Irrigation Projects. Interim Report. Denver, Colorado, November 1970.

25. U.S. Water Resource Council. 1972 OBERS Projections, Volumes 1-7. Washington, D.C: U.S. Government Printing Office, April 1974.

26. U.S. Water Resource Council. 1972 OBERS Projections, Agricultural Supplement. Washington, D.C.: U.S. Government Printing Office, 1975.

27. Wade, James, C. "Stream Sediment Movement, Water Quality and Agricultural Production: A modeling Approach to Economic and Environmental Analysis." Unpublished Ph.D. dissertation, Iowa State University, Ames, 1975.

28. Wade, James C. and Earl O. Heady. "Controlling Nonpoint Sediment Sources with Cropland Management: A National Economic Assessment." American Journal of Agricultural Economics 59(1) (February 1977): 13-24.

29. Wadleigh, Cecil H. "Wastes in Relation to Agriculture and Forestry." USDA Miscellaneous Publications No. 1065, March 1968.

30. Wischmeier, Walter H. and Smith, Dwight D. Predicting Rainfall and Erosion Losses from Cropland East of the Rocky Mountains. USDA Agriculture Handbook No. 282, May 1963.

ADDITIONAL COPIES of this publication can be obtained by writing the Center for Agricultural and Rural Development, 578 East Hall, Iowa State University, Ames, IA 50011. Price is $2 each.